UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH
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CMCiB Comparative Medicine & Bioimage Centre of Catalonia
IGTP Germans Trias i Pujol Research Institute

Daily report 06-05-2020

Analysis and prediction of COVID-19 for EU-EFTA-UK and other countries

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Foreword

The present report aims to provide a comprehensive picture of the **pandemic situation of COVID-19** in the EU countries, and to be able to foresee the situation in the next coming days.

We employ an **empirical model**, verified with the evolution of the number of confirmed cases in previous countries where the epidemic is close to conclude, including all provinces of China. The model does not pretend to interpret the causes of the evolution of the cases but to permit the **evaluation of the quality of control measures made in each state** and a **short-term prediction of trends**. Note, however, that the effects of the measures' control that start on a given day are not observed until approximately 7-10 days later.

The model and predictions are based on two parameters that are daily fitted to available data:

- ✓ *a*: the velocity at which spreading specific rate slows down; the higher the value, the better the control.
- ✓ *K*: the final number of expected cumulated cases, which cannot be evaluated at the initial stages because growth is still exponential.

We show an individual report with 8 graphs and a table with the **short-term predictions** for different countries and regions. We are adjusting the model to **countries and regions** with at least 4 days with more than 100 confirmed cases and a current load over 200 cases. The **predicted period** of a country depends on the number of datapoints over this 100 cases threshold, and is of 5 days for those that have reported more than 100 cumulated cases for 10 consecutive days or more. For short-term predictions, we assign higher weight to last 3 points in the fittings, so that changes are rapidly captured by the model. The whole methodology employed in the inform is explained in the last pages of this document.

In addition to the individual reports, the reader will find an initial dashboard with a brief analysis of the situation in EU-EFTA-UK countries, some summary figures and tables as well as **long-term predictions** for some of them, when possible. These long-term predictions are evaluated without different weights to data-points. We also discuss a specific issue every day.

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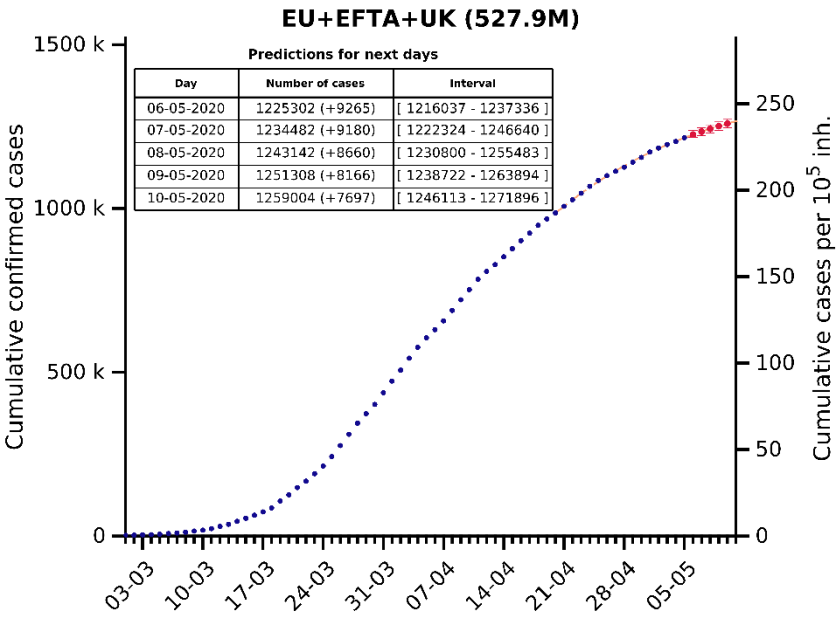
(0) Executive summary – Dashboard

Global EU+EFTA+UK trends and needs

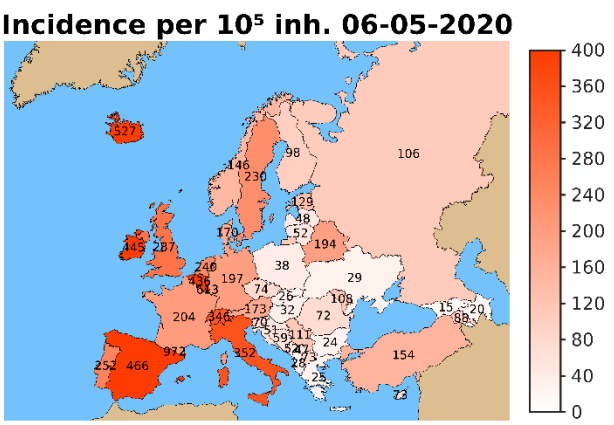
EU+EFTA+UK keep following last days' trend, with around 10,000 new cases per day and a ρ_7 of 0.8. It is now at the level of 230 cases per 100,000 inhabitants, similar to the one in Sweden. Highest reported attack rate corresponds to Luxembourg (665) followed by Iceland (494), Spain (470), Ireland (460) and Belgium (442). Fortunately, all these countries are intermediate or low risk, with promising trends.

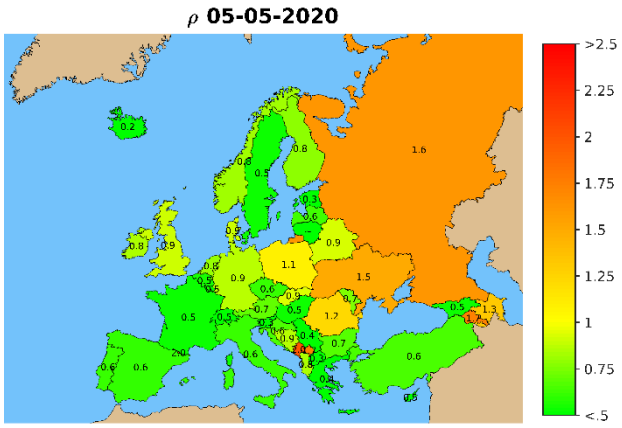


In the Analysis section we discuss the possibility of deconfining countries as a whole and defend the need for look at inter-region heterogeneity and adapt the protocols, if necessary.

Trends for specific countries

Denmark seems having stuck at the level of around 100-150 daily new cases. This can be related with deconfinement measures that started being implemented in mid-April. Nevertheless, no secondary outbreaks are suggested by the data. This means that the country is capable of maintaining this incidence level. **United Kingdom** keeps at the level of 4,000 daily new cases, and is the only country with a ρ_7>1.





Situation and trends per country

Table of current situation in EU countries. Colour scale is relative except when indicated, this means that it is applied independently to each column, and distinguishes best (green) form worst (red) situations according to each of the variables. **New!** Last column (**EPG_{EST}**) indicates EPG assessed with **estimated real 14-day attack rate** (see report from 22/04 for details). **EPG_{REP}** is calculated with **data reported by countries**. EPG_{REP} and EPG_{EST} **cannot be compared between them** because scales are different, but can be independently used for estimating risk of countries according to reported or estimated real situation, respectively.

	Reported data						Indexes		
Country	Cumulative cases	Attack rate /10^5 inh.	Cumulative deaths	Mortality /10^5 inh.	Active cases (last 14 days)	14-day attack rate /10^5 inh.	ρ_7 (1)	EPG_{REP} (2)	EPG_{EST} (3)
Spain	219,329	473.2	25,613	55.3	24,945	53.8	0.65	35	416
Italy	213,013	358.4	29,315	49.3	29,056	48.9	0.76	37	510
United Kingdom	194,990	293.5	29,427	44.3	65,946	99.3	1.05	104	1,689
Germany	164,897	201.3	6,996	8.5	19,203	23.4	0.76	18	82
France	132,967	205.4	25,531	39.4	15,643	24.2	0.68	16	334
Belgium	50,509	444.7	8,016	70.6	9,553	84.1	0.60	50	843
Netherlands	41,087	241.9	5,168	30.4	6,953	40.9	0.74	30	390
Switzerland	29,926	349.2	1,482	17.3	1,945	22.7	0.71	16	81
Portugal	25,702	247.8	1,074	10.4	4,323	41.7	0.55	23	102
Sweden	23,216	236.0	2,854	29.0	7,894	80.2	0.88	70	1,044
Ireland	21,983	465.2	1,339	28.3	5,943	125.8	0.66	83	530
Austria	15,586	178.9	606	7.0	753	8.6	0.68	6	23
Poland	14,431	37.8	716	1.9	4,575	12.0	0.89	11	64
Romania	13,837	70.0	827	4.2	4,595	23.2	0.97	22	154
Denmark	9,821	171.9	503	8.8	2,126	37.2	0.87	32	174
Norway	7,903	147.2	209	3.9	737	13.7	0.75	10	28
Czech Republic	7,896	74.4	257	2.4	855	8.1	0.81	6	23
Finland	5,412	98.3	246	4.5	1,398	25.4	0.90	23	122
Luxembourg	3,840	666.7	96	16.7	222	38.5	0.90	35	NA
Hungary	3,111	31.9	373	3.8	943	9.7	0.82	8	112
Greece	2,642	23.6	146	1.3	241	2.2	0.85	2	13
Croatia	2,112	50.1	83	2.0	204	4.8	0.62	3	NA
Iceland	1,799	493.9	10	2.7	21	5.8	0.51	3	NA
Estonia	1,711	130.4	55	4.2	159	12.1	0.51	6	NA
Bulgaria	1,689	23.7	78	1.1	714	10.0	0.71	7	NA
Slovenia	1,445	69.5	98	4.7	105	5.1	0.49	2	NA
Lithuania	1,423	48.9	46	1.6	53	1.8	NA	NA	NA
Slovakia	1,421	26.1	25	0.5	222	4.1	0.59	2	NA
Latvia	896	45.5	17	0.9	148	7.5	0.80	6	NA
Cyprus	878	75.0	20	1.7	94	8.0	0.96	8	NA
Malta	482	112.4	5	1.2	39	9.1	NA	NA	NA
Liechtenstein	83	215.3	1	2.6	1	2.6	NA	NA	NA
	Scale								
	Worst	Worst	Worst	Worst	Worst	Worst	2.0	200	2000
	Best	Best	Best	Best	Best	Best	0.0	0	0

(1) ρ_3 is the average of 7 consecutive ρ, but can still fluctuate. (2) EPG stands for Effective Growth Potential. EPG_{REP} is obtained by multiplying attack rate of last 14 days per 10^5 inhabitants (i.e. density of cases) by ρ_3 (a value related with effective reproduction number and that, therefore, determines the dynamics for subsequent days). EPG_{EST} is obtained by multiplying estimated real attack rate of last 14 days per 10^5 inhabitants by ρ_3.

Highlights for countries with highest number of reported cases

- ✓ UK remains at the level of 4,000 cases per day and with a $\rho_7 > 1$. The number of deaths reported in this country has overcome the number reported by Italy.
- ✓ Spain, Italy, France and Germany maintain the trend of previous days.

Time indicators by country

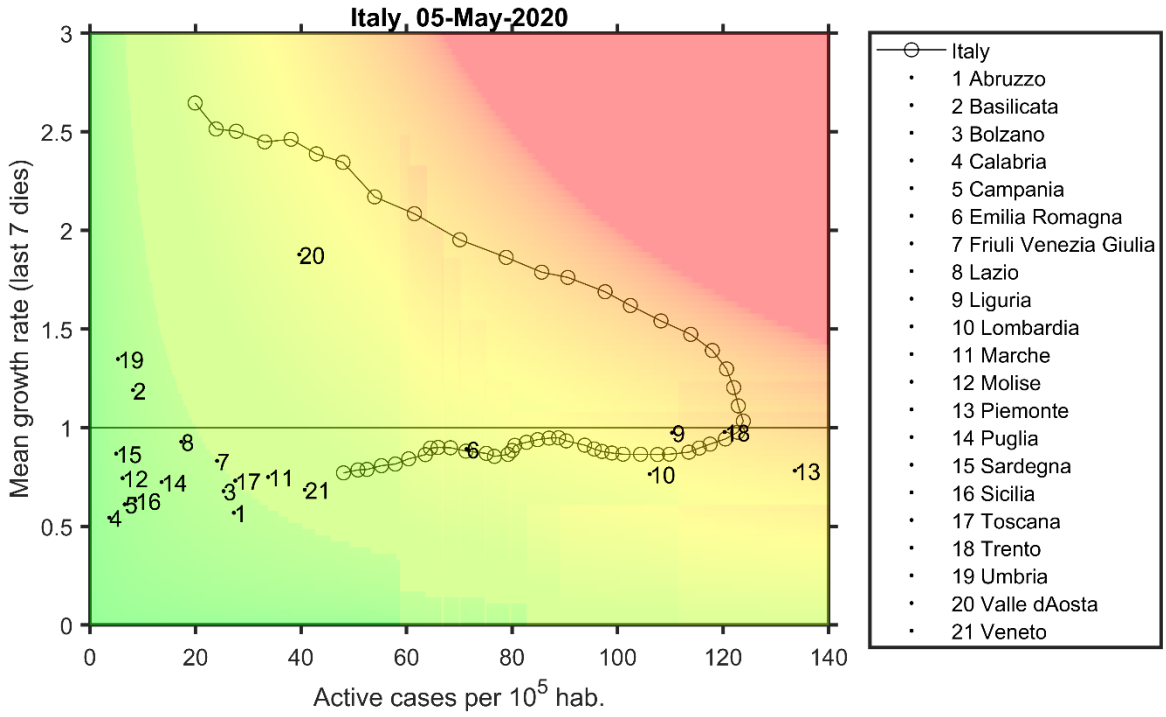
This table summarizes a few time indicators for each country: time since 50 cases were reported, time interval between an attack rate of $1/10^5$ inhabitants and an attack rate of $10/10^5$ inhabitants, and time interval between attack rates of 10 to 100 per 10^5 inhabitants (only for countries that have overtaken this threshold).

Countries	Days since the first 50 cases	Time interval between 1 and 10 cases / 105 inh. (days)	Time interval between 10 and 100 cases / 105 inh. (days)
Italy	74	11	16
France	68	10	20
Germany	68	12	17
Spain	66	7	12
United Kingdom	64	11	19
Norway	63	9	24
Switzerland	63	9	12
Netherlands	62	11	20
Sweden	62	10	28
Austria	61	10	14
Belgium	61	11	14
Greece	60	18	NA
Iceland	60	5	15
Denmark	58	4	30
Czech Republic	57	11	NA
Finland	56	12	NA
Portugal	56	9	15
Slovenia	56	6	NA
Ireland	55	8	18
Romania	55	15	NA
Estonia	54	5	30
Poland	54	17	NA
Bulgaria	52	26	NA
Luxembourg	52	6	7
Slovakia	52	24	NA
Croatia	51	12	NA
Latvia	50	12	NA
Cyprus	49	12	NA
Hungary	49	20	NA
Malta	48	8	34
Lithuania	47	9	NA
Liechtenstein	42	9	11

Analysis: Can countries be deconfined as a whole?

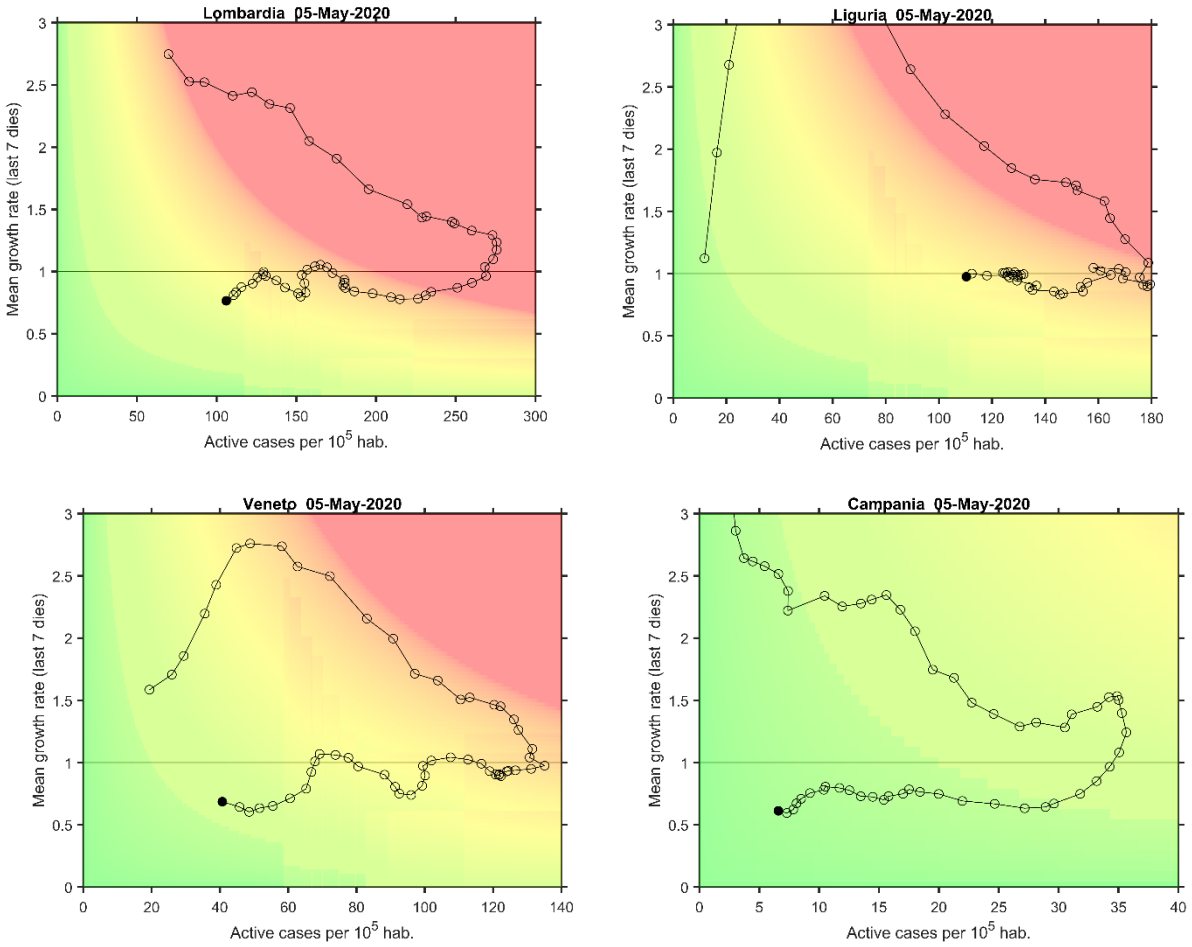
Since mid-April, several European countries are gradually implementing deconfinement measures such as re-opening primary schools (Denmark, 15th April), kindergartens (20th April, Norway) and some stores (Italy, 11th April), or the relaxation of other measures like full lock down (13th April, Spain) and limits in public gathering (Czech Republic, 20th April)[1], among others. **Specific protocols for deconfinement measures are, in general, designed by country-level governments**. Nevertheless, it is essential to **analyse heterogeneity inside countrie**s, if exists, so that deconfinement measures can be adapted to each zone according to its particular risk level.

Let us analyse the case of Italy. In the following figure, we show **the risk diagram of the country with the current situation of all Italian regions**. Although most of the regions are at the green zone corresponding to low risk, there are a few other regions at the yellow zone (e.g. Emilia Romagna and Valle d'Aosta), which defines intermediate risk, and four regions in the orange zone that represents intermediate-high risk level (Lombardia, Liguria, Trento and Piemonte).

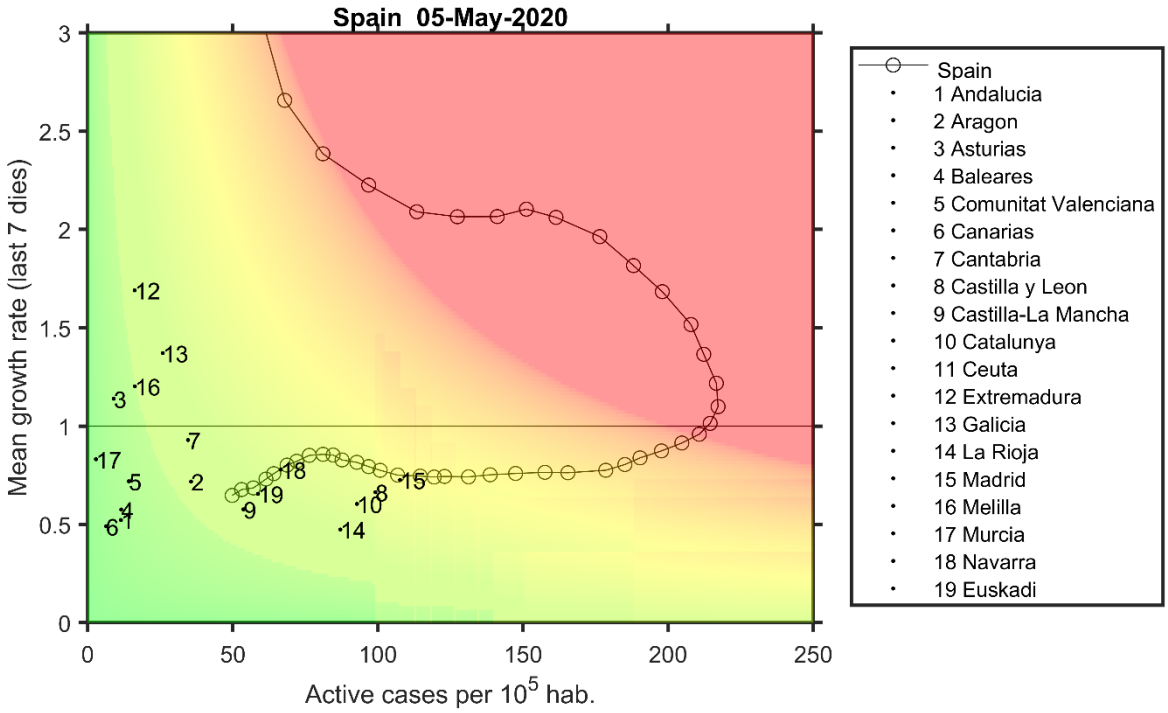


If we look at the particular risk diagram of some of these countries, we observe a variety of dynamics that reflect huge differences in the epidemiological cycle and situation. While the four regions present a growth rate below 1, the incidence of active cases among these regions is quite different. Thus, the actual situation in Campania is much better than in Liguria. The x-axis has been adjusted to fit with the scale of the scatter plot, but the colour scale permits comparisons.

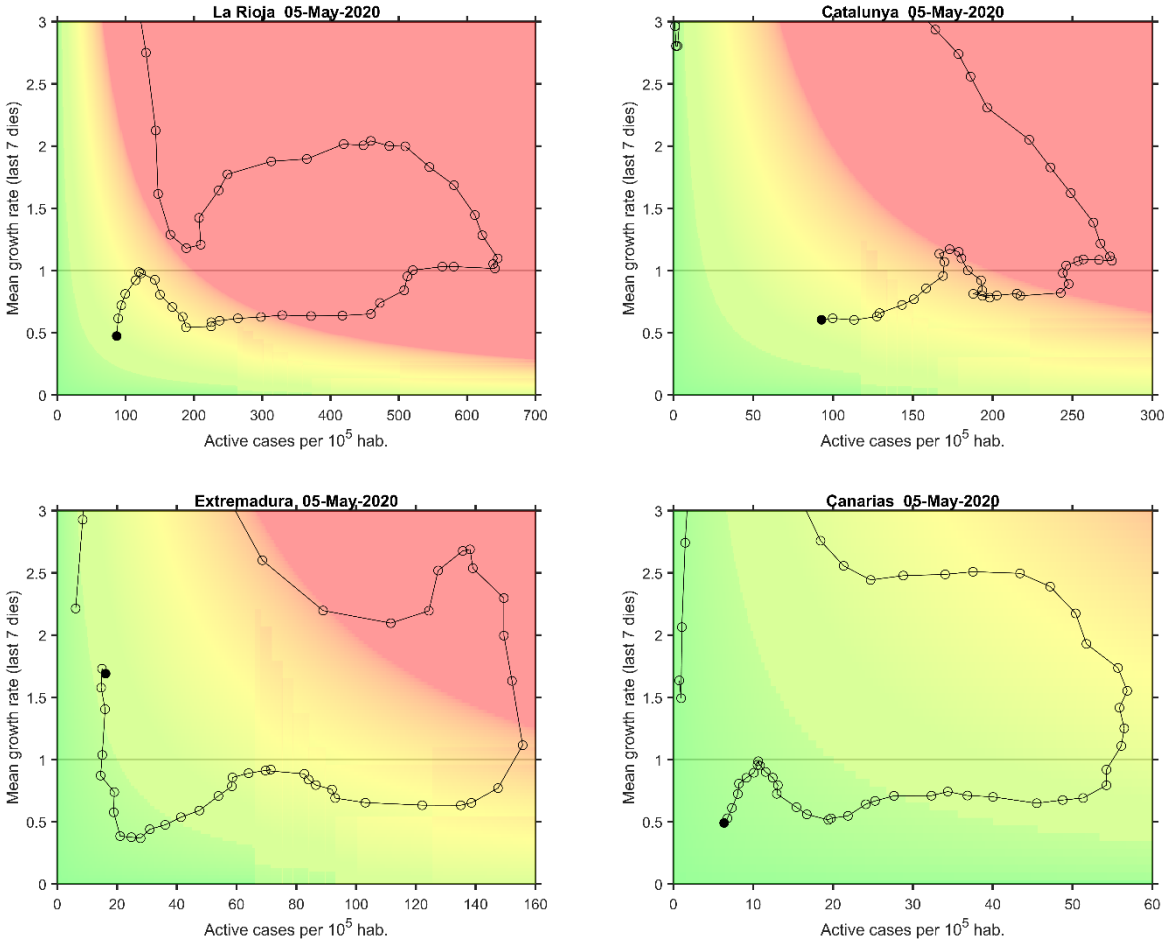
[1] https://www.acaps.org/covid19-government-measures-dataset



Let us now look at Spain. Again, the **risk diagram of the whole country hides different situations of its regions**, shown as points in the next figure. The diagram shows no countries at the high-risk zone, but still a few of them in the intermediate one (yellow) such as Madrid, Castilla y León, Catalunya and La Rioja, among others.



The next set of four risk diagrams corresponding to different Spanish regions illustrates such diversity or heterogeneity inside the country.



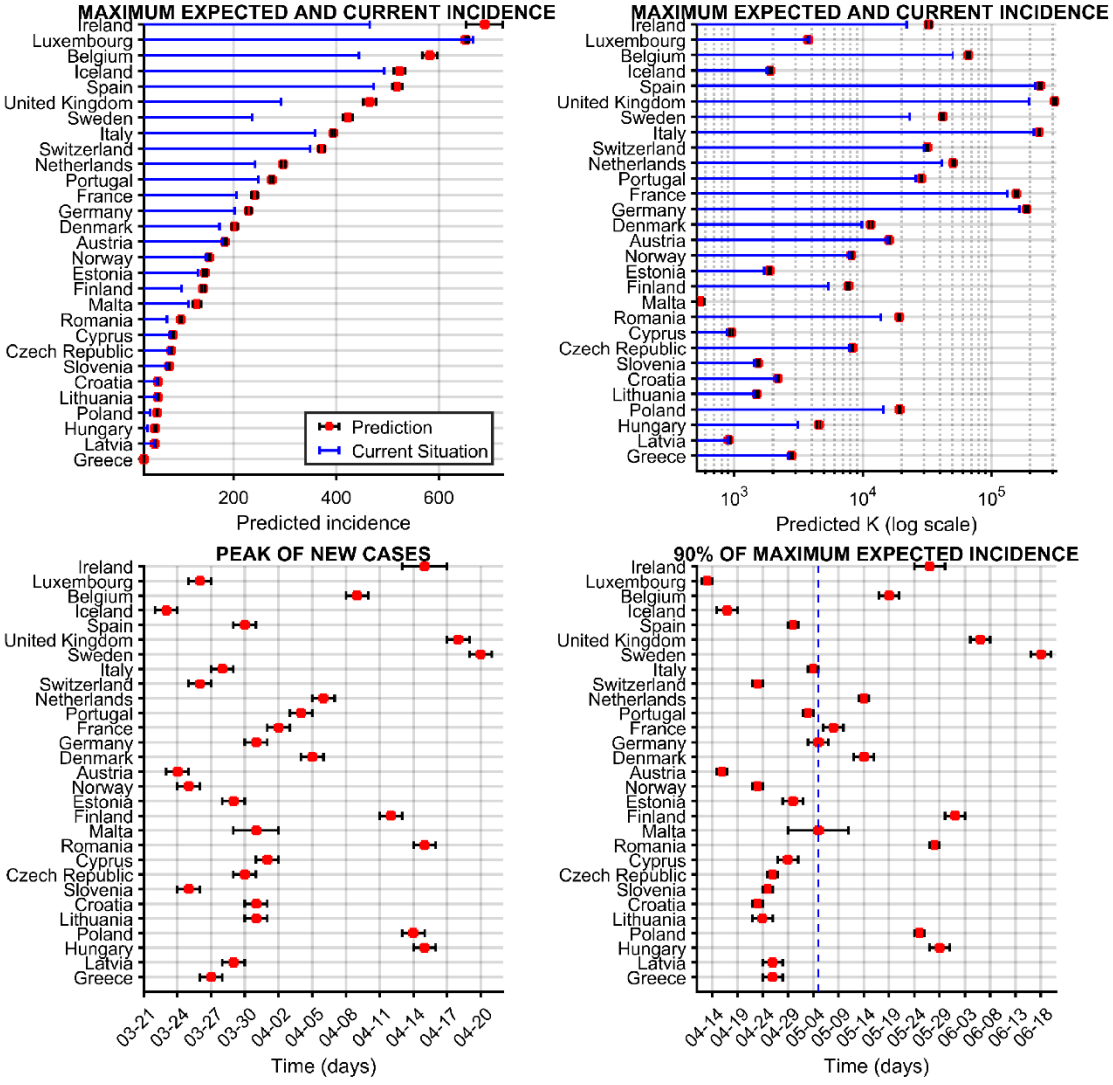
These diagrams demonstrate the need for a **careful analysis of heterogeneity among regions, and even inside such regions**. Is it evident that the situation in Canarias islands is far from the one found in Catalunya, or that Lombardia and Campania have radically different levels of risk. If a deconfinement measure is applied to the whole country, the risk of secondary outbreaks in those regions with worse situation is high.

Last but not least, **low risk (green zone) is not synonym of absence of risk at all**. In order to maintain a country inside this region, testing, health care and contact tracing strategies must operate as perfect gears. In addition, countries must have enough protection material for sanitary workers and general population. The level of risk can be quantified with the EPG (Effective Potential Growth), which is the product of 7-day average of spreading rate (ρ_7) and 14-day cumulative incidence (A_{14}). In fact, it represents an order of magnitude of expected cases per 100,000 inhabitants for the following 14 days. Policy makers can establish a local indicative scale like this one, that would be refined according to **diagnosis, health care and contact tracing capacity of each region**:

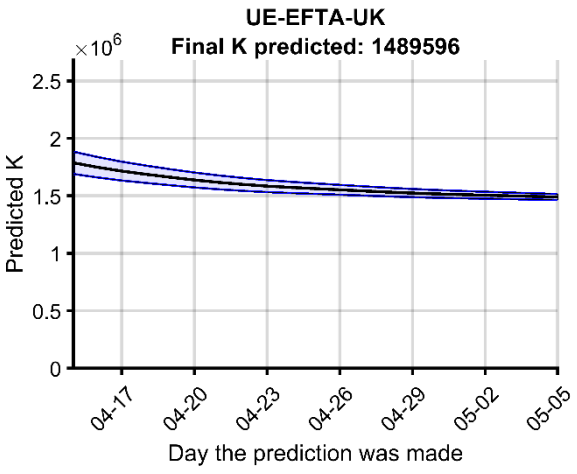
- EPG < 30: Low risk
- 30<EPG<70: Intermediate risk
- 70<EPG<100: Intermediate-high risk
- EPG>100: High risk

Long-term predictions

Long-term predictions, evaluated with the **whole historical series** and without weighting last 3 points. Up-left: Predictions of maximum incidences per country (total final expected attack rate per 10^5 inh.). Up-right: Predictions of maximum absolute number of cases per country (K, in log scale). Blue lines indicate current situation. Bottom-left: Time in which peak in new cases was achieved / will be achieved. Bottom-right: Time at which 90 % of K was achieved / will be achieved. Blue dotted line indicates current date.



Final expected K for UE+EFTA+UK. Evolution of predicted K with time, where convergence to best estimate is seen. Last prediction is numerically shown in title.



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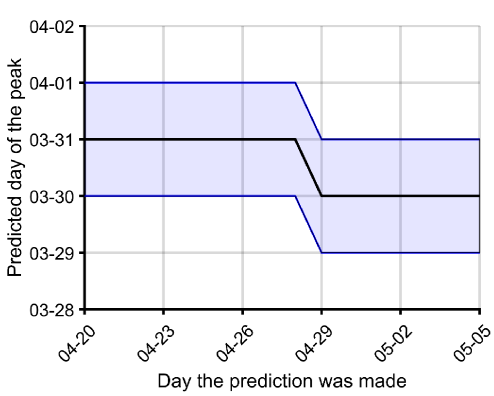
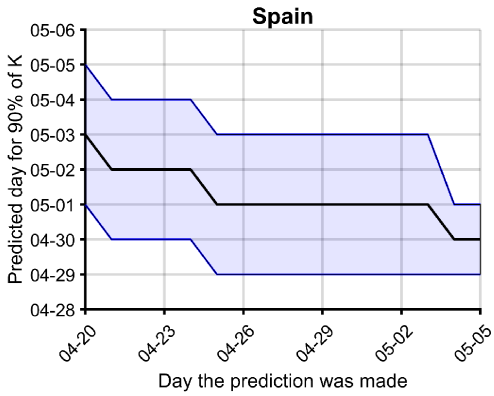
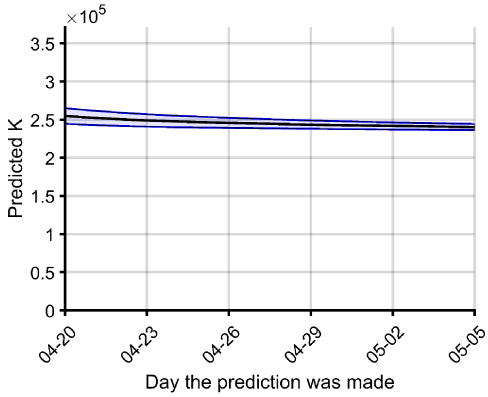
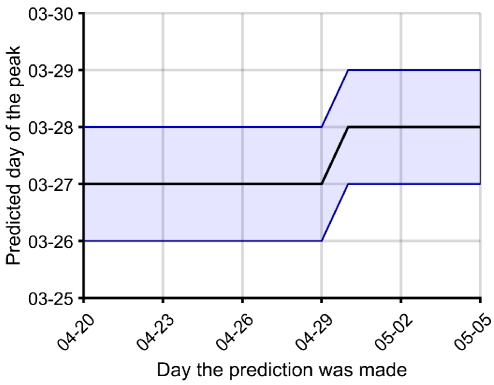
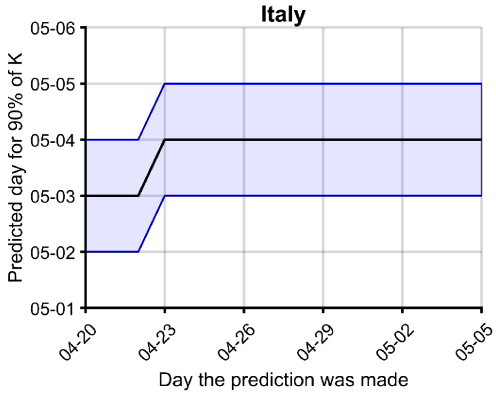
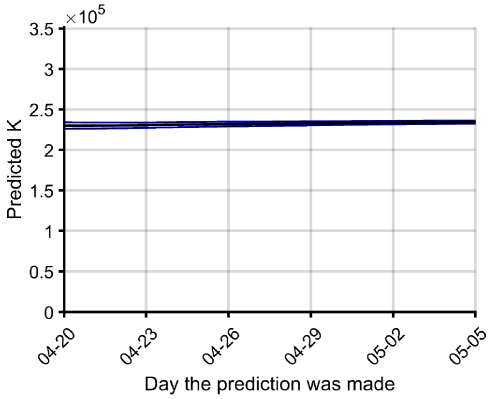

Predicted day of the peak
04-02
04-01
03-31
03-30
03-29
03-28
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made

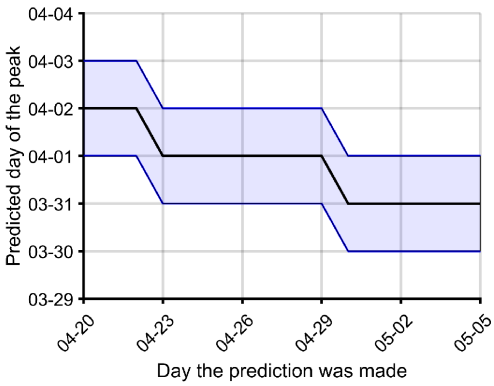

Spain
Predicted day for 90% of K
05-06
05-05
05-04
05-03
05-02
05-01
04-30
04-29
04-28
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made

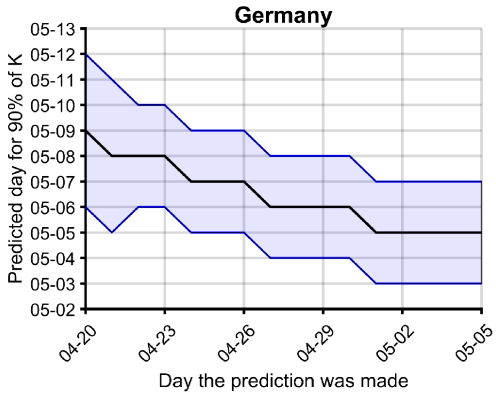

×10^5
Predicted K
3.5
3
2.5
2
1.5
1
0.5
0
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made

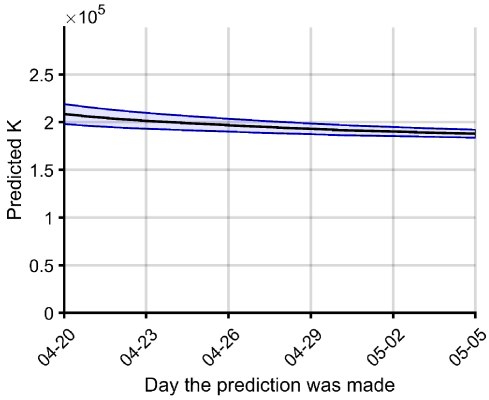

Predicted day of the peak
03-30
03-29
03-28
03-27
03-26
03-25
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made

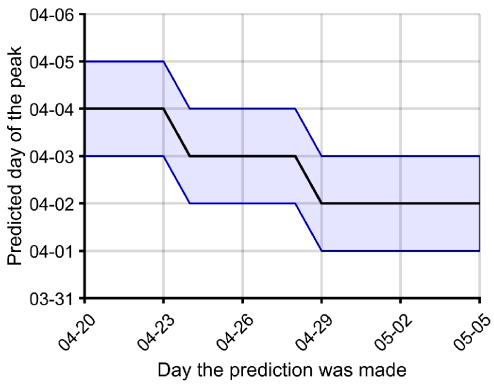

Italy
Predicted day for 90% of K
05-06
05-05
05-04
05-03
05-02
05-01
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made


×10^5
Predicted K
3.5
3
2.5
2
1.5
1
0.5
0
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made


Predicted day of the peak
04-04
04-03
04-02
04-01
03-31
03-30
03-29
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made


Germany
Predicted day for 90% of K
05-13
05-12
05-11
05-10
05-09
05-08
05-07
05-06
05-05
05-04
05-03
05-02
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made


×10^5
Predicted K
2.5
2
1.5
1
0.5
0
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made


Predicted day of the peak
04-06
04-05
04-04
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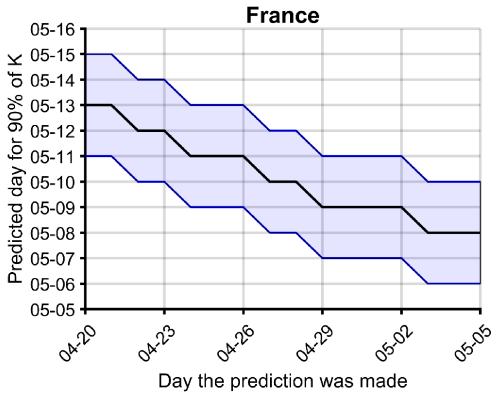
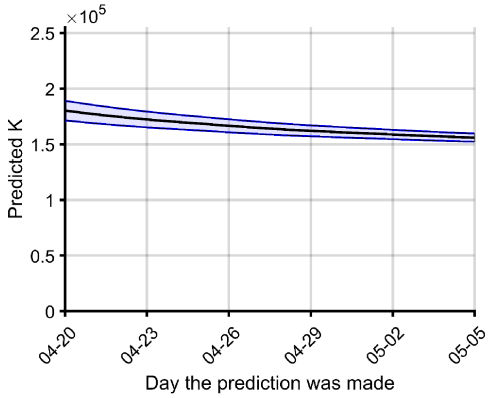
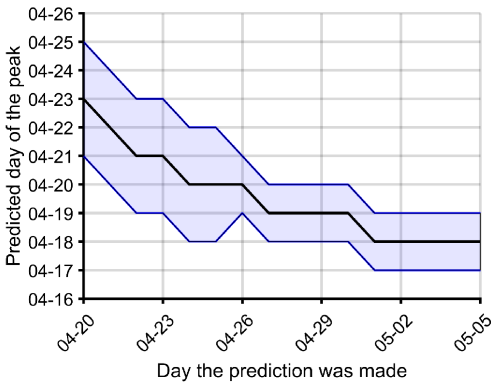
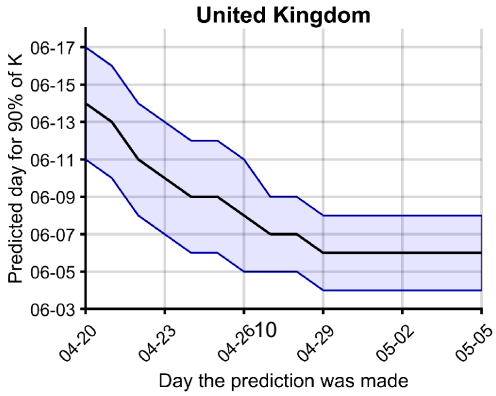
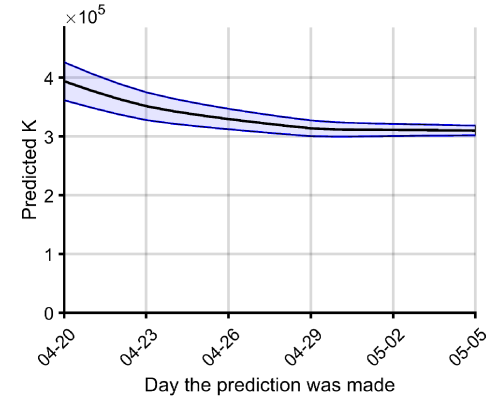
04-02
04-01
03-31
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made


France
Predicted day for 90% of K
05-16
05-15
05-14
05-13
05-12
05-11
05-10
05-09
05-08
05-07
05-06
05-05
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made

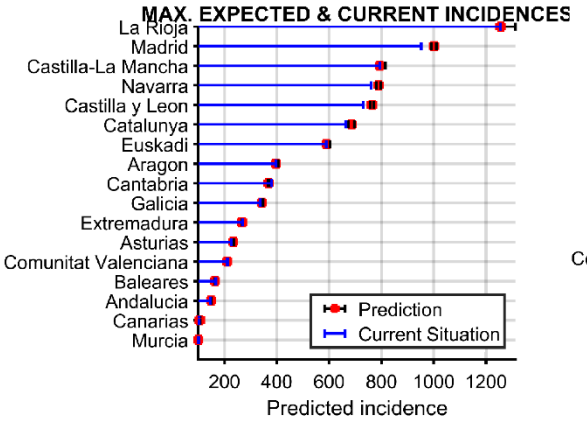

×10^5
Predicted K
2.5
2
1.5
1
0.5
0
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made

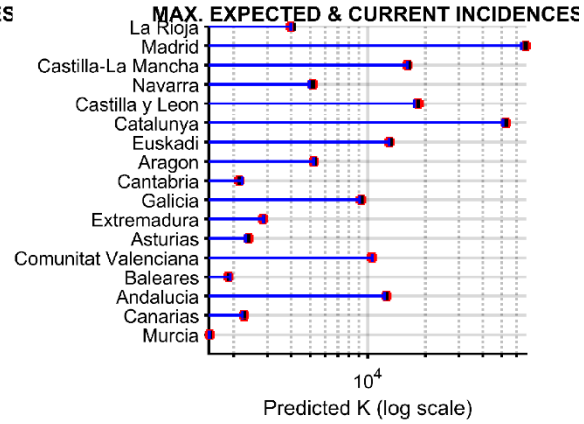

Predicted day of the peak
04-26
04-25
04-24
04-23
04-22
04-21
04-20
04-19
04-18
04-17
04-16
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made

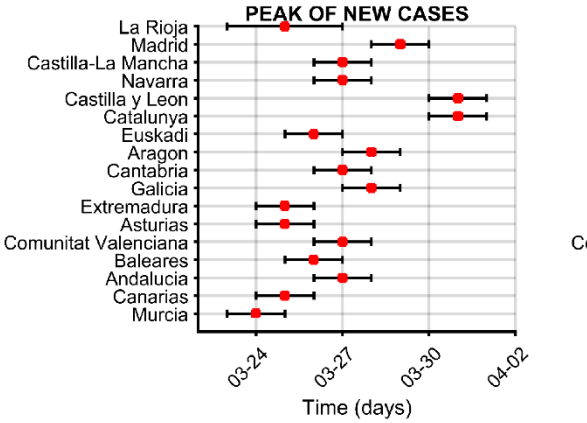

United Kingdom
Predicted day for 90% of K
06-17
06-15
06-13
06-11
06-09
06-07
06-05
06-03
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made

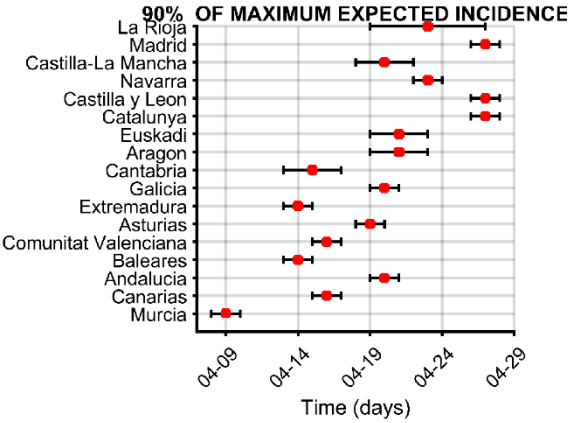

×10^5
Predicted K
4
3
2
1
0
04-20
04-23
04-26
04-29
05-02
05-05
Day the prediction was made

Italian regions

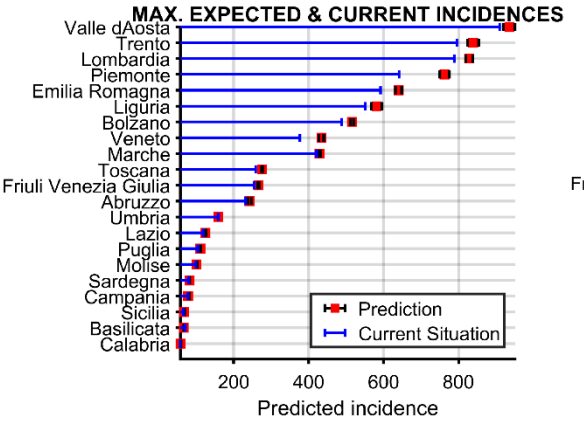


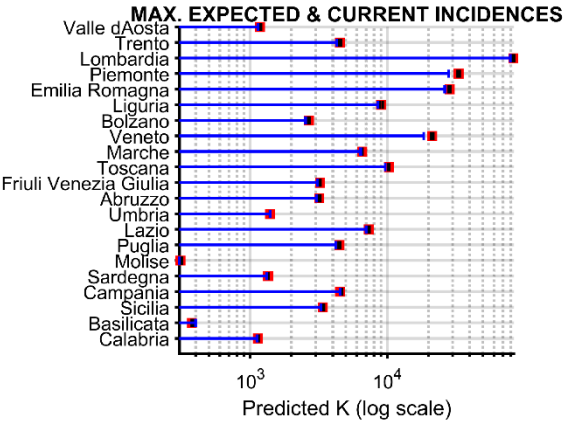


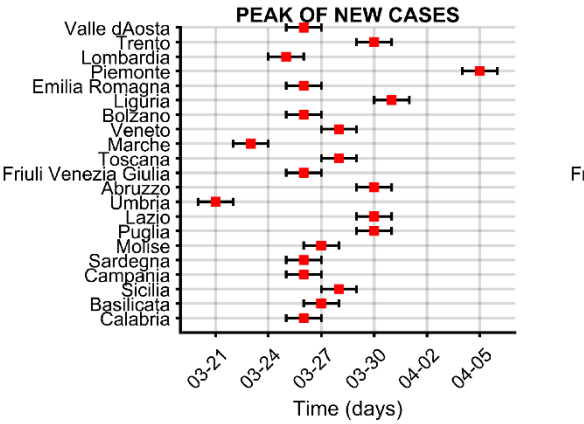


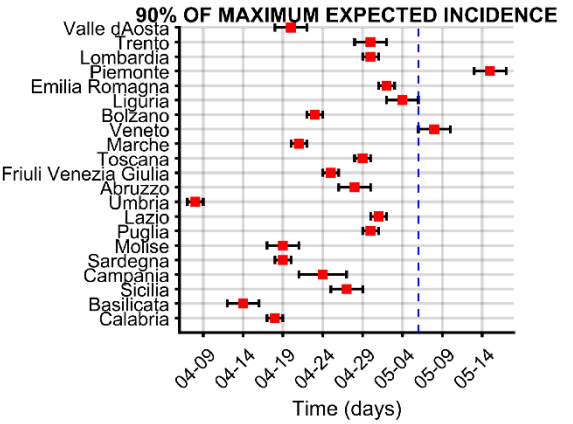


Spanish regions

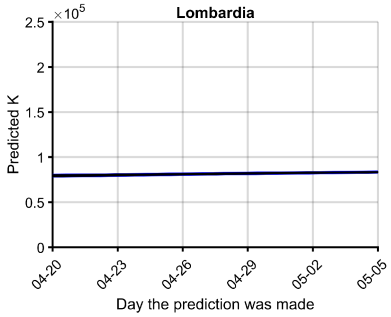


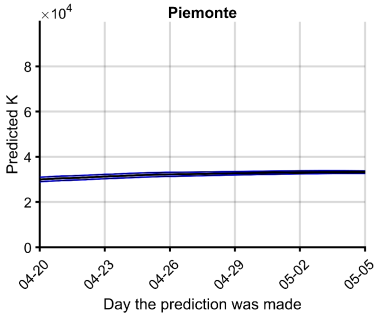


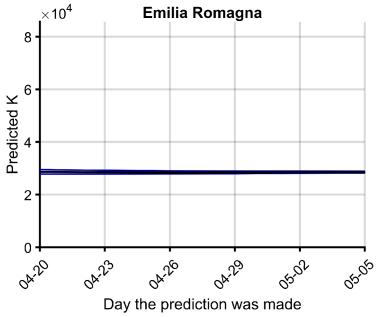


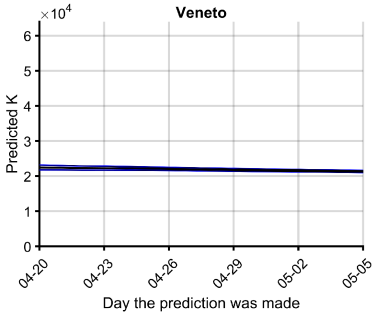


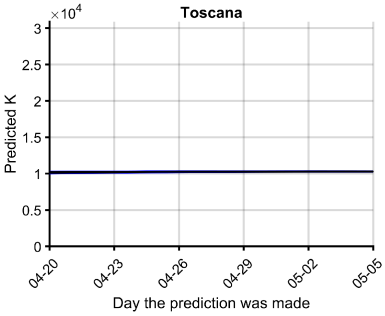
2020-05-06

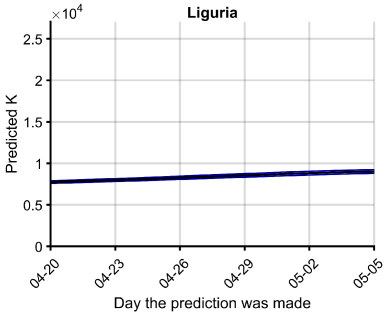

Lombardia
×10^5
Predicted K
Day the prediction was made

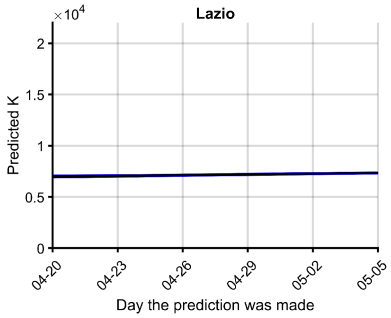

Piemonte
×10^4
Predicted K
Day the prediction was made

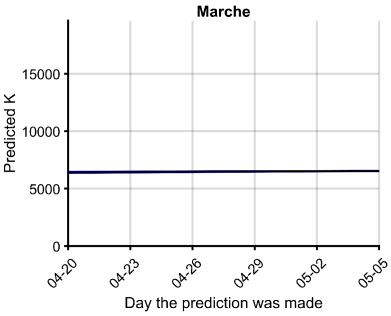

Emilia Romagna
×10^4
Predicted K
Day the prediction was made

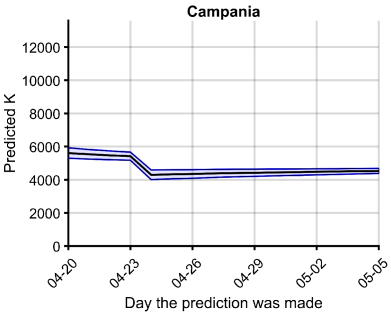

Veneto
×10^4
Predicted K
Day the prediction was made

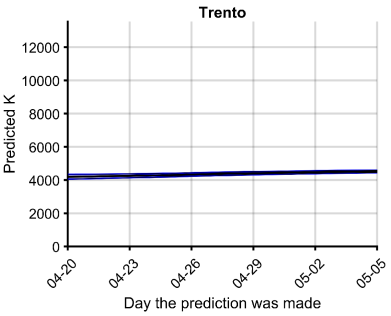

Toscana
×10^4
Predicted K
Day the prediction was made

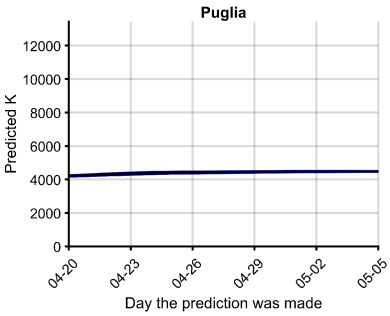

Liguria
×10^4
Predicted K
Day the prediction was made

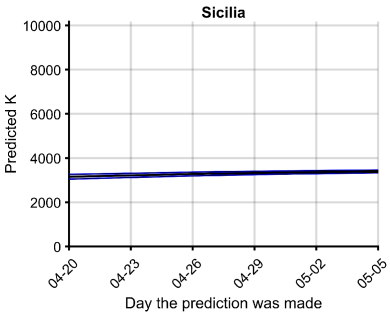

Lazio
×10^4
Predicted K
Day the prediction was made

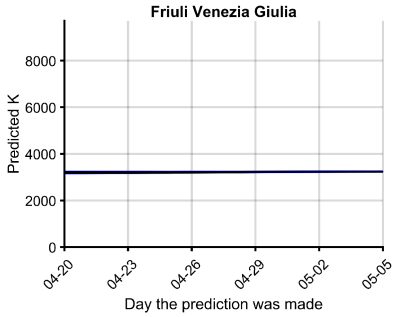

Marche
Predicted K
Day the prediction was made

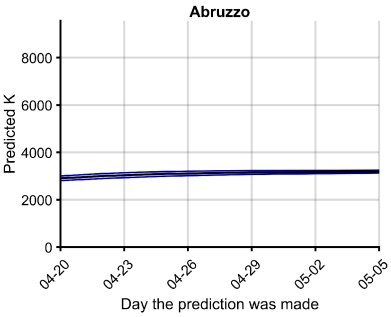

Campania
Predicted K
Day the prediction was made

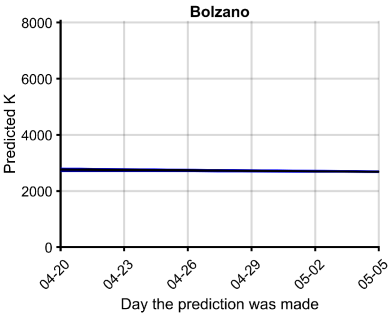

Trento
Predicted K
Day the prediction was made

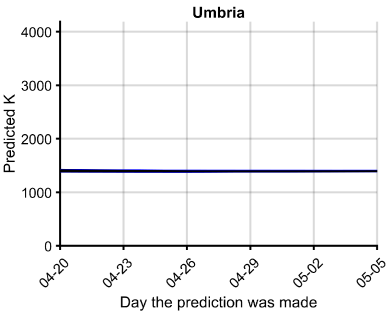

Puglia
Predicted K
Day the prediction was made

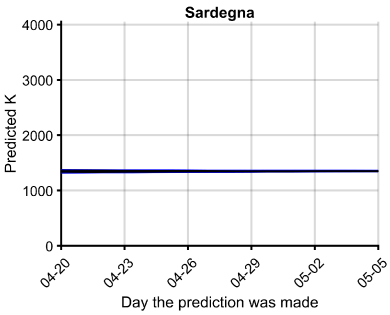

Sicilia
Predicted K
Day the prediction was made

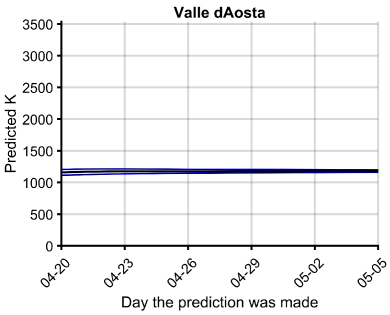

Friuli Venezia Giulia
Predicted K
Day the prediction was made

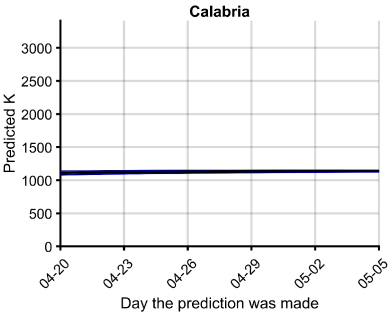

Abruzzo
Predicted K
Day the prediction was made

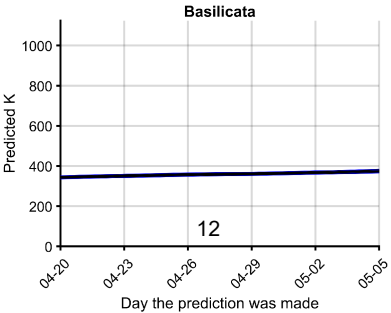

Bolzano
Predicted K
Day the prediction was made

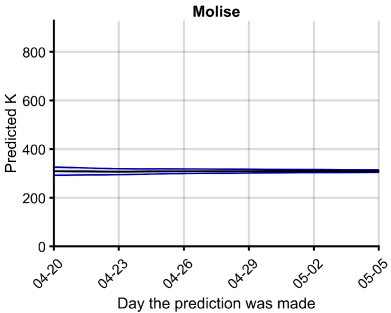

Umbria
Predicted K
Day the prediction was made


Sardegna
Predicted K
Day the prediction was made

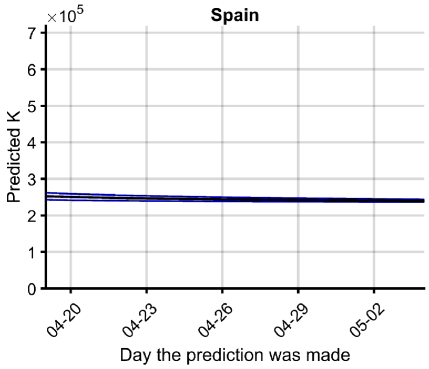

Valle dAosta
Predicted K
Day the prediction was made

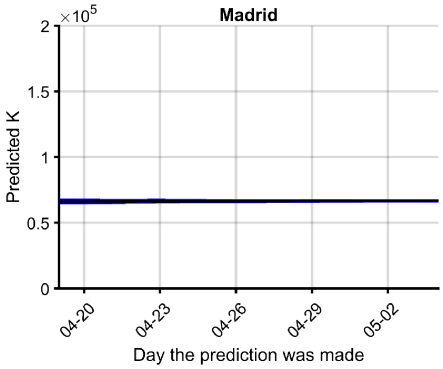

Calabria
Predicted K
Day the prediction was made

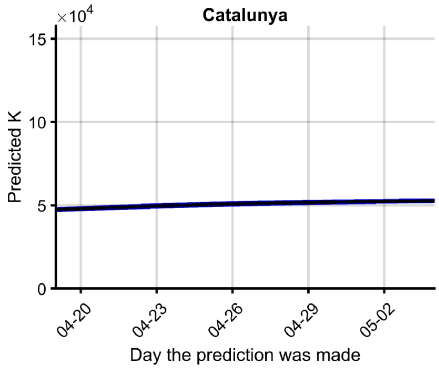

Basilicata
Predicted K
Day the prediction was made

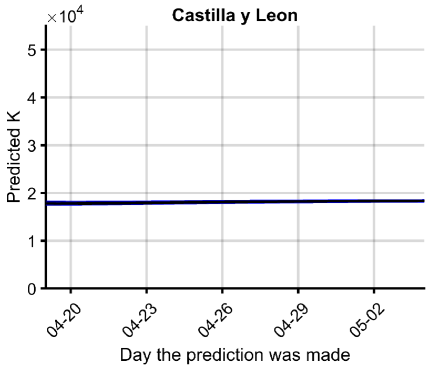

Molise
Predicted K
Day the prediction was made

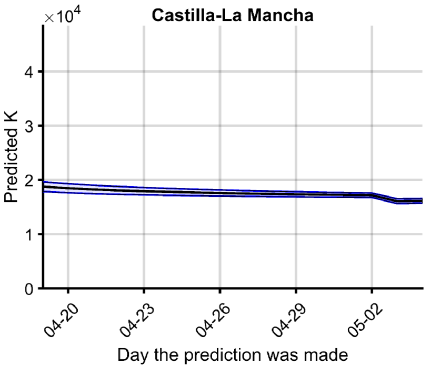
2020-05-05

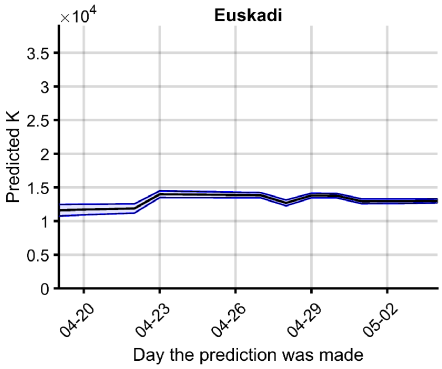

Spain
×10^5
Predicted K
Day the prediction was made

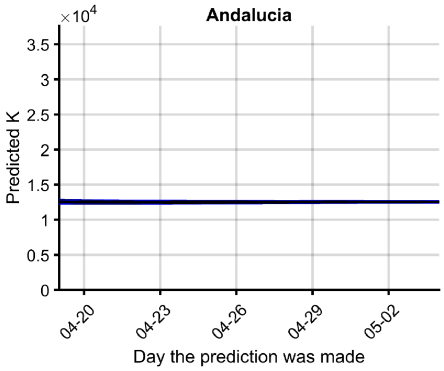

Madrid
×10^5
Predicted K
Day the prediction was made

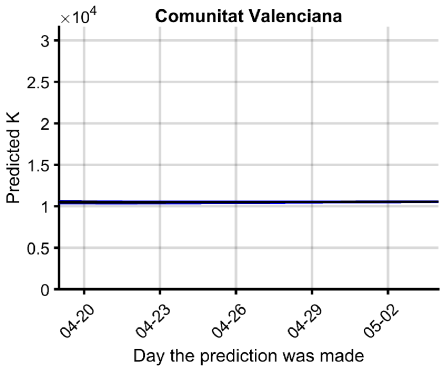

Catalunya
×10^4
Predicted K
Day the prediction was made

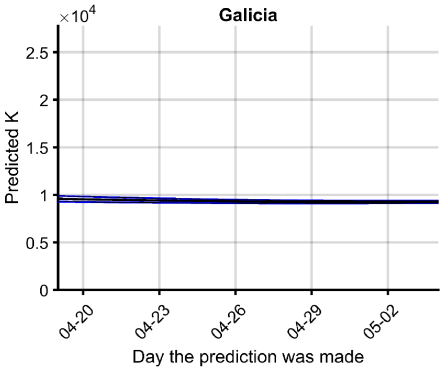

Castilla y Leon
×10^4
Predicted K
Day the prediction was made

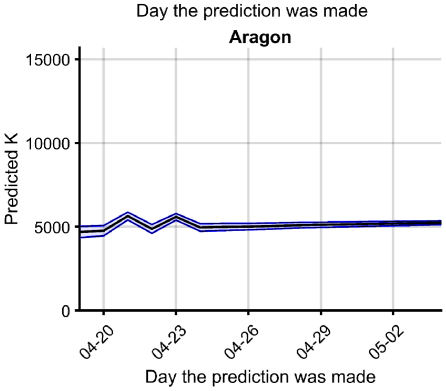

Castilla-La Mancha
×10^4
Predicted K
Day the prediction was made

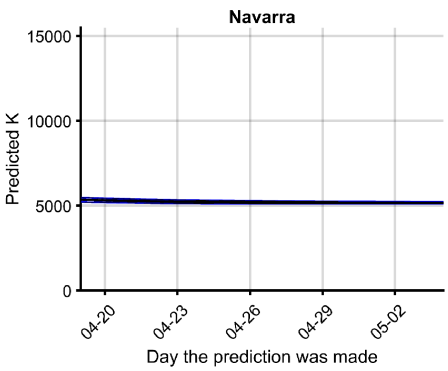

Euskadi
×10^4
Predicted K
Day the prediction was made

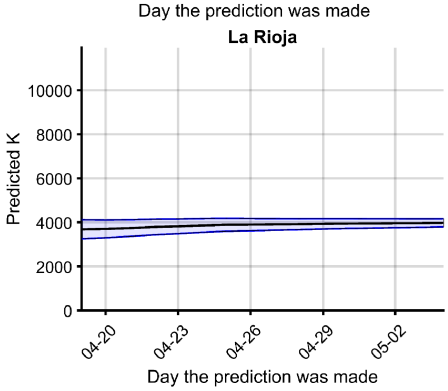

Andalucia
×10^4
Predicted K
Day the prediction was made

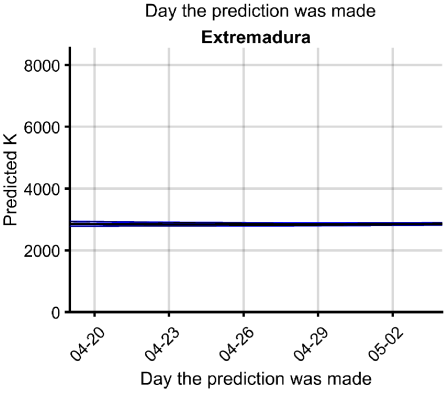

Comunitat Valenciana
×10^4
Predicted K
Day the prediction was made

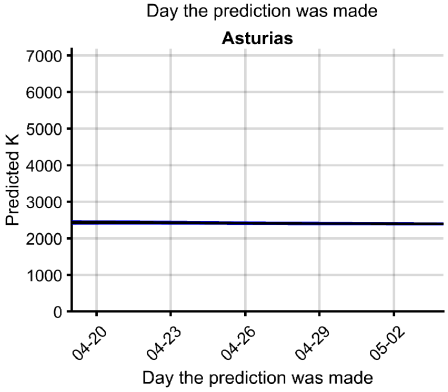

Galicia
×10^4
Predicted K
Day the prediction was made

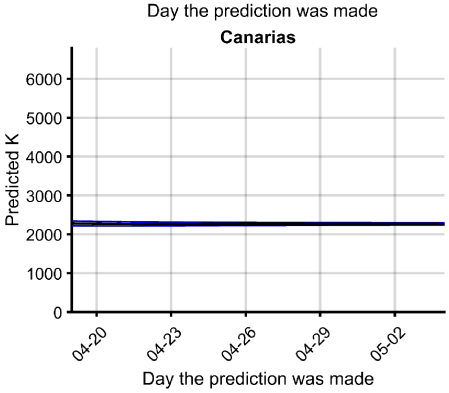

Aragon
Predicted K
Day the prediction was made

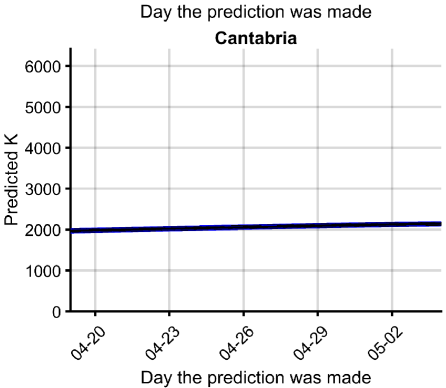

Navarra
Predicted K
Day the prediction was made

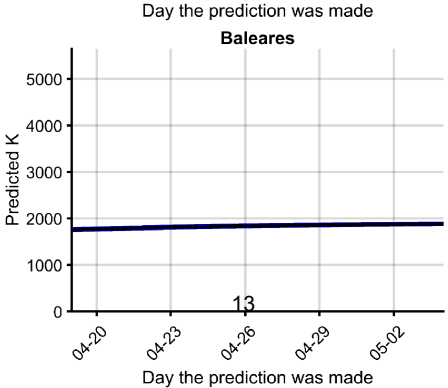

La Rioja
Predicted K
Day the prediction was made

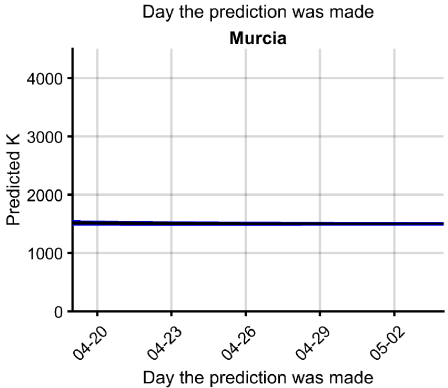

Extremadura
Predicted K
Day the prediction was made


Asturias
Predicted K
Day the prediction was made


Canarias
Predicted K
Day the prediction was made


Cantabria
Predicted K
Day the prediction was made


Baleares
Predicted K
Day the prediction was made


Murcia
Predicted K
Day the prediction was made

Situation and trends in Italian and Spanish regions

Italy

	Reported data						Indexes		
Country	Cumulative cases	Attack rate / 10^5 inh.	Cumulative deaths	Mortality / 10^5 inh.	Active cases (last 14 days)	14-day attack rate / 10^5 inh	ρ_7 [1]	EPG_{REP} [2]	EPG_{EST} [3]
Lombardia	79.369	790,4	14.611	145,5	10.277	102,3	0,78	80	1.515
Piemonte	27.939	641,3	3.247	74,5	5.200	119,4	0,77	92	1.124
Emilia Romagna	26.379	591,5	3.737	83,8	2.945	66,0	0,80	53	764
Veneto	18.479	376,7	1.568	32,0	1.741	35,5	0,74	26	241
Toscana	9.657	258,9	899	24,1	957	25,7	0,72	18	181
Liguria	8.551	551,4	1.243	80,2	1.633	105,3	0,73	77	1.161
Lazio	6.995	119,0	538	9,2	1.020	17,3	0,81	14	113
Marche	6.421	421,0	943	61,8	497	32,6	0,82	27	403
Campania	4.532	78,1	376	6,5	347	6,0	0,72	4	36
Trento	4.280	399,2	437	40,8	634	59,1	0,60	35	715
Puglia	4.196	104,1	438	10,9	466	11,6	0,79	9	99
Sicilia	3.281	65,6	250	5,0	398	8,0	0,65	5	41
Friuli Venezia Giulia	3.094	254,6	306	25,2	277	22,8	0,54	12	122
Abruzzo	3.047	232,3	341	26,0	314	23,9	0,82	20	230
Bolzano	2.543	2.367,0	286	266,2	127	118,2	0,51	61	137
Umbria	1.404	159,2	70	7,9	47	5,3	0,91	5	NA
Sardegna	1.319	80,4	119	7,3	72	4,4	0,70	3	29
Valle d'Aosta	1.146	912,4	139	110,7	51	40,6	1,13	46	563
Calabria	1.122	57,6	89	4,6	62	3,2	0,57	2	NA
Basilicata	399	70,9	25	4,4	45	8,0	NA	NA	NA
Molise	304	99,5	22	7,2	20	6,5	0,51	3	NA
	Scale								
	Worst	Worst	Worst	Worst	Worst	Worst	2,0	200	2000
	Best	Best	Best	Best	Best	Best	0,0	0	0

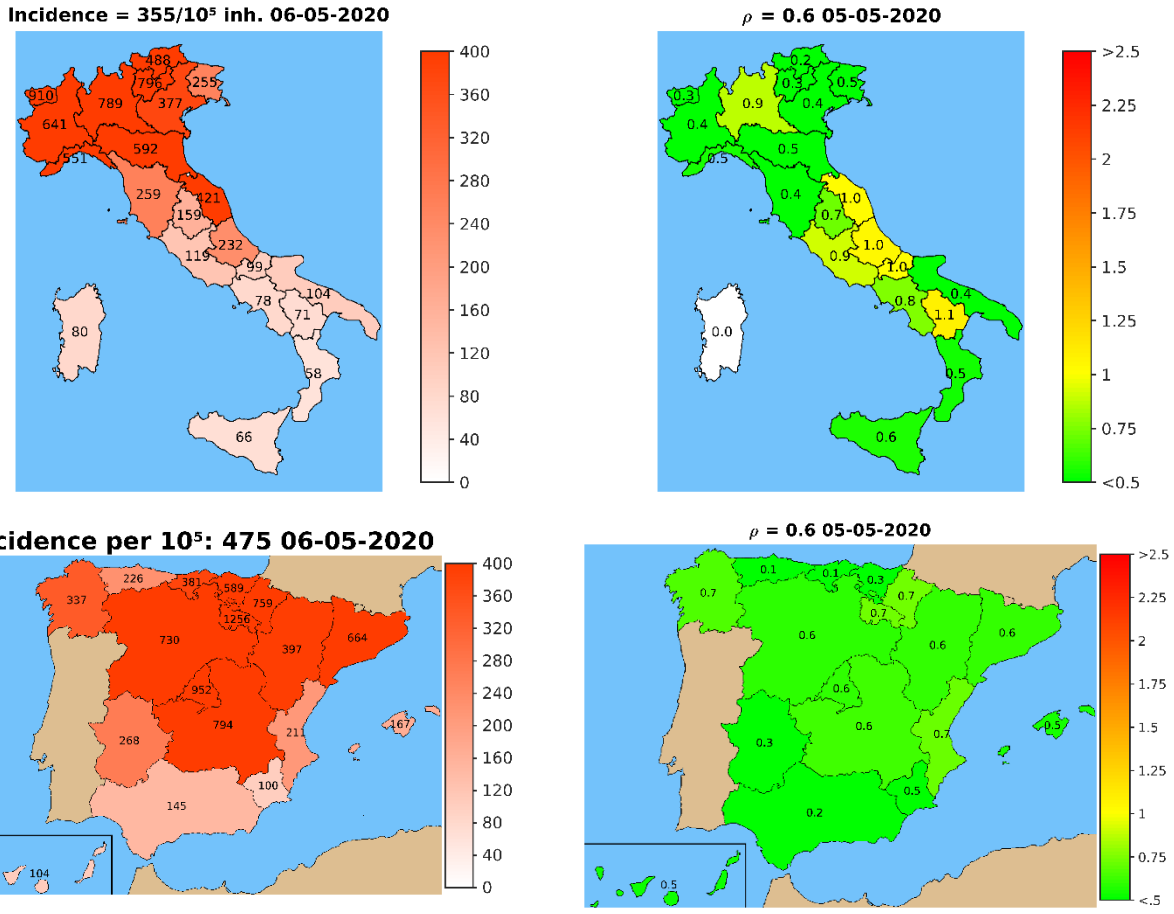
Spain

	Reported data						Indexes		
Autonomous regions	Cumulative cases	Attack rate /10^5 inh.	Cumulated deaths	Mortality rate /10^5 inh.	Active cases (last 14 days)	14-day attack rate /10^5 inh.	ρ_7 [1]	EPG_{REP} [2]	EPG_{EST} [3]
Madrid	63,416	955.0	8,466	127.5	7,171	108.0	0.75	81	1,111
Catalunya	50,924	673.1	5,345	70.7	7,122	94.1	0.61	57	610
Castilla y Leon	17,520	727.5	1,847	76.7	2,379	98.8	0.62	61	647
Castilla-La Mancha	16,144	793.1	2,647	130.0	1,091	53.6	0.63	34	570
Euskadi	13,008	597.2	1,364	62.6	1,296	59.5	0.54	32	343
Andalucia	12,236	145.2	1,281	15.2	966	11.5	0.40	5	49
Comunitat Valenciana	10,537	211.8	1,291	26.0	712	14.3	0.72	10	130
Galicia	9,097	336.9	582	21.6	699	25.9	1.56	40	274
Aragon	5,231	396.0	788	59.7	470	35.6	0.8	27	430
Navarra	4,966	764.0	476	73.2	435	66.9	0.71	47	478
La Rioja	3,980	1,269.2	337	107.5	276	88.0	0.48	42	350
Extremadura	2,865	268.9	463	43.5	173	16.2	1.49	24	389
Asturias	2,310	226.0	287	28.1	92	9.0	1.07	10	131
Canarias	2,231	101.1	143	6.5	137	6.2	0.48	3	19
Cantabria	2,213	380.4	199	34.2	201	34.6	0.67	23	221
Baleares	1,921	161.7	199	16.8	133	11.2	0.6	6	72
Murcia	1,498	100.7	136	9.1	43	2.9	0.87	3	24
Melilla	119	140.5	2	2.4	14	16.5	NA	NA	NA
Ceuta	109	128.5	4	4.7	9	10.6	NA	NA	NA
	Scale								
	Worst	Worst	Worst	Worst	Worst	Worst	2.0	200	2000
	Best	Best	Best	Best	Best	Best	0.0	0	0

[1] ρ_3 is the average of 7 consecutive ρ, but can still fluctuate. [2] EPG stands for Effective Growth Potential. EPG_{REP} is obtained by multiplying attack rate of last 14 days per 10^5 inhabitants (i.e. density of cases) by ρ_3 (a value related with effective reproduction number and that, therefore, determines the dynamics for subsequent days). EPG_{EST} is obtained by multiplying estimated real attack rate of last 14 days per 10^5 inhabitants by ρ_3.

Maps of Italian and Spanish regions

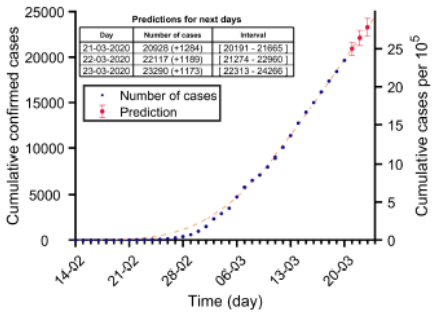
Cumulative incidence and spreading rate (ρ) in Italian and Spanish regions.

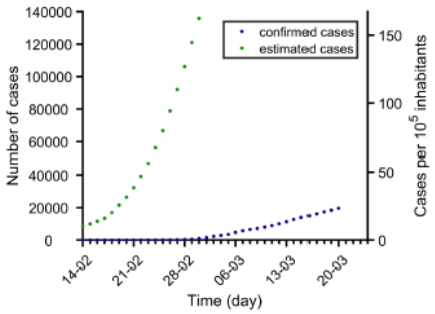


Legend: Countries' reports details

Iran 20-03-2020. Population: 83.7M. Current cumulated incidence: $23/10^5$

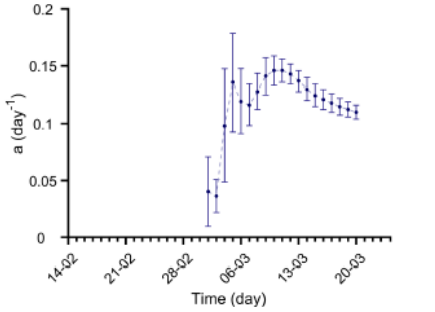
Confirmed cases: data (blue), model fitted (dashed line), predictions (red points and table)

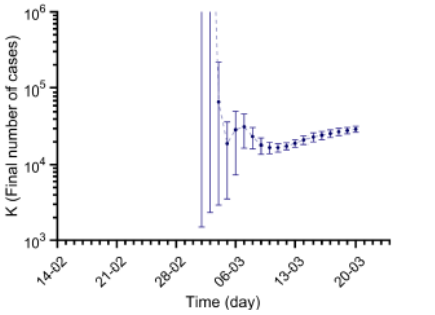




Estimated cases using death rate (see Methods)

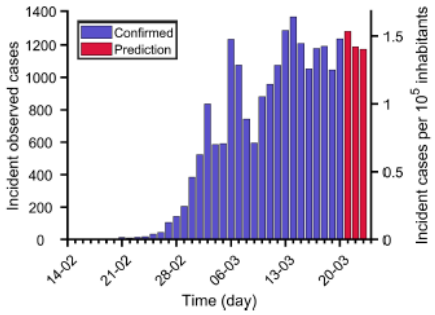
Fitted *a* value using points prior to each date

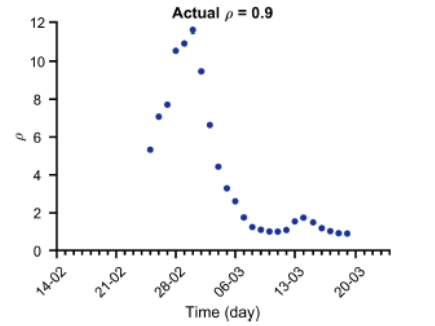




Fitted *K* value using points prior to each date

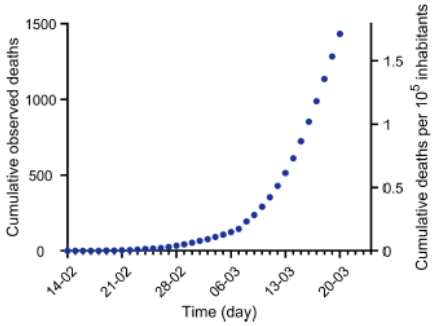
Reported and predicted new cases

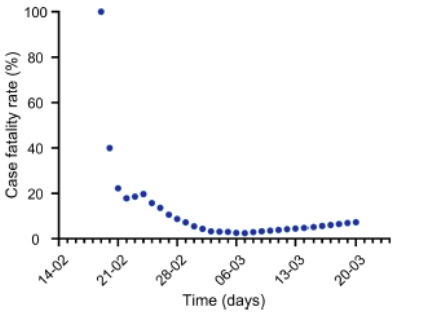




Evolution of ρ, a parameter related with Reproduction number (see Methods)

Reported deaths



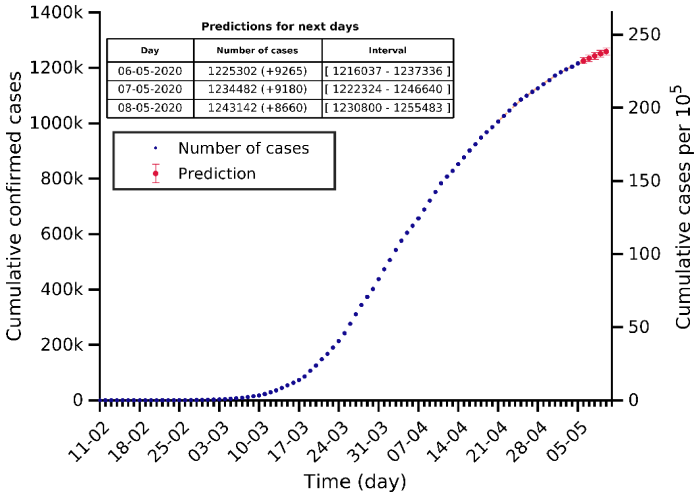


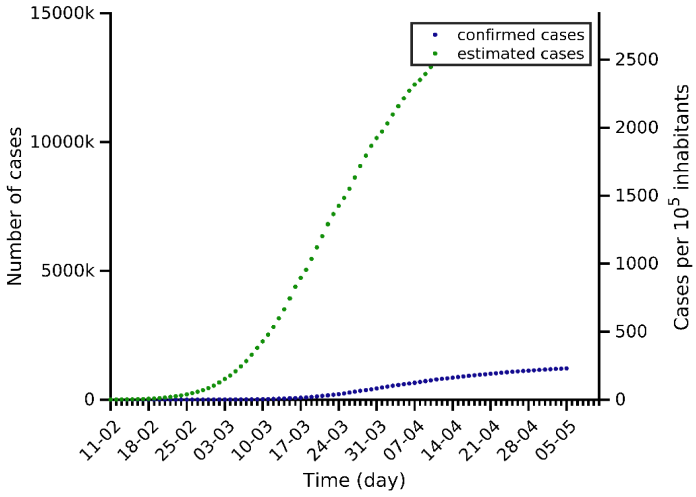
Deaths / cumulated reported cases

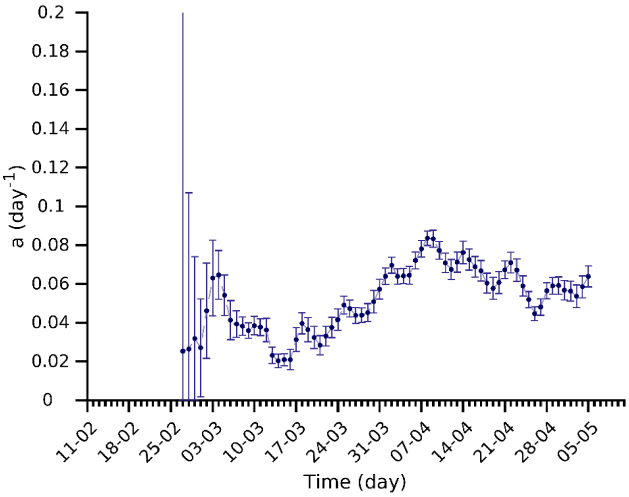
(1) Analysis and prediction of COVID-19 for EU+EFTA+UK

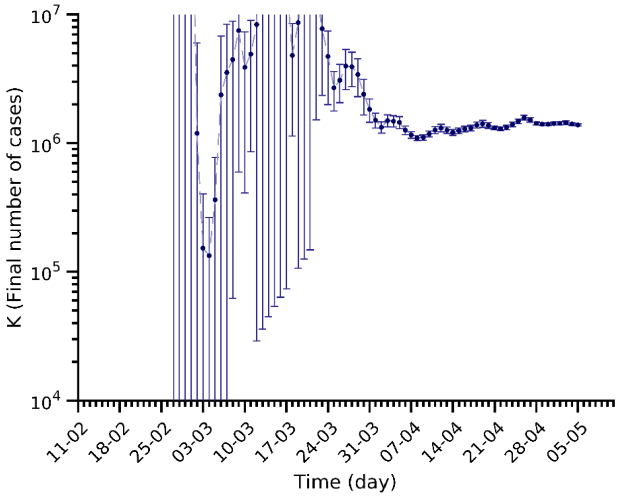
Data obtained from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases

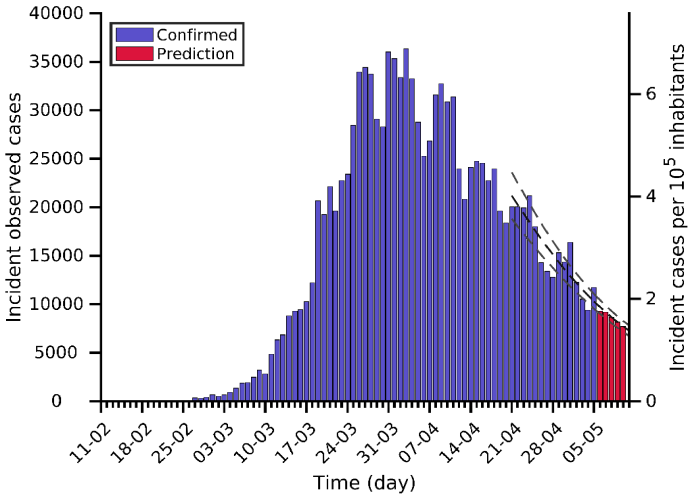
EU+EFTA+UK 05-05-2020. Population: 527.9M. Current cumulated incidence: 230/1

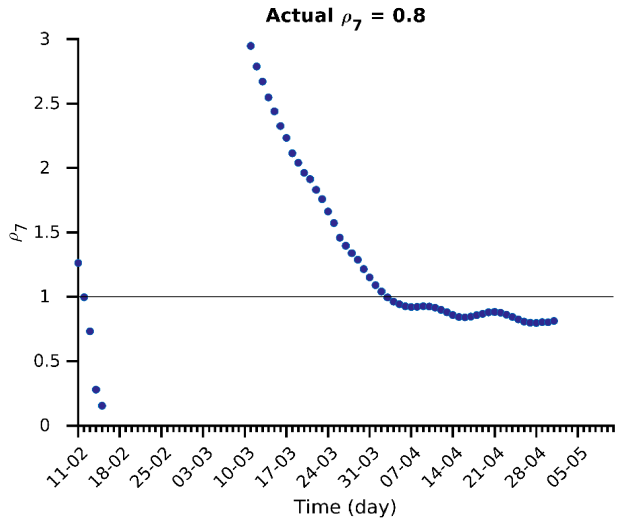


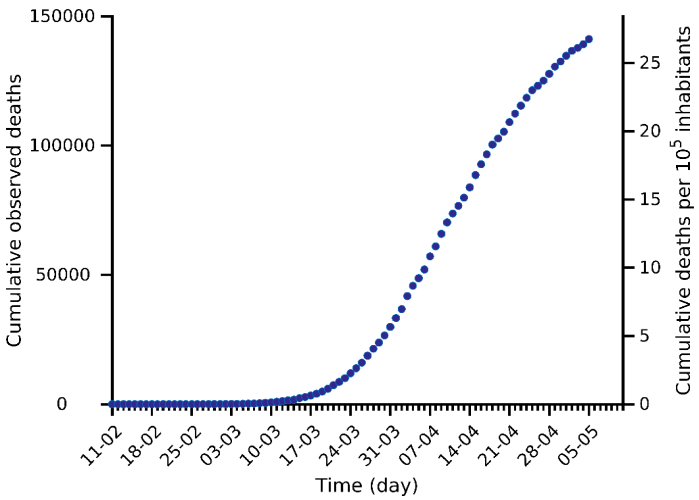


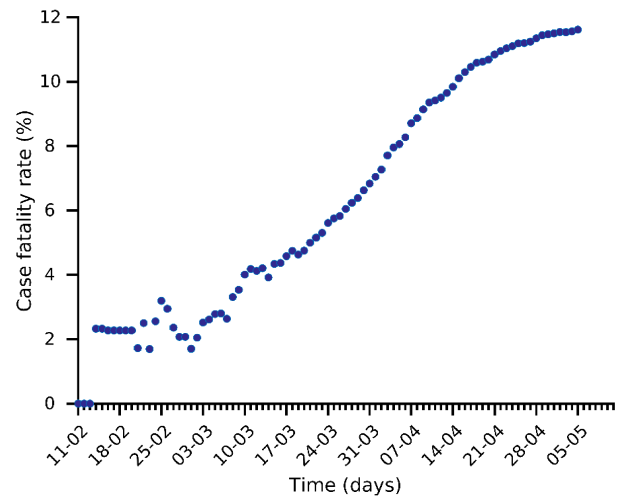




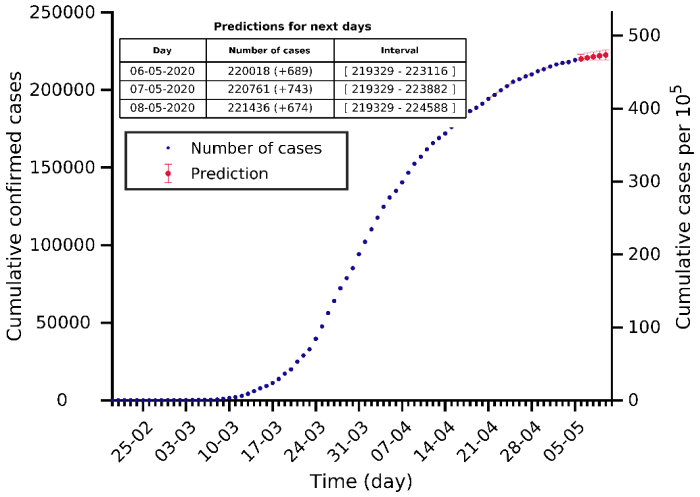


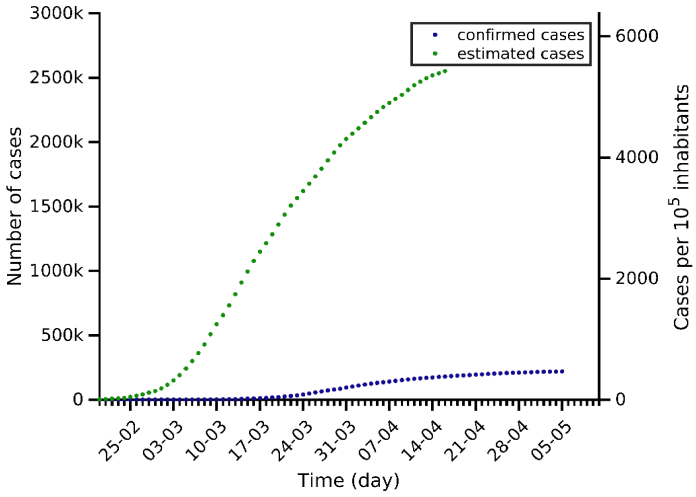


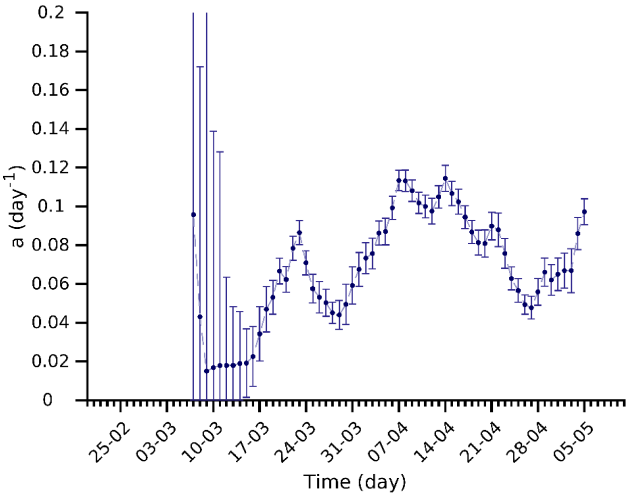


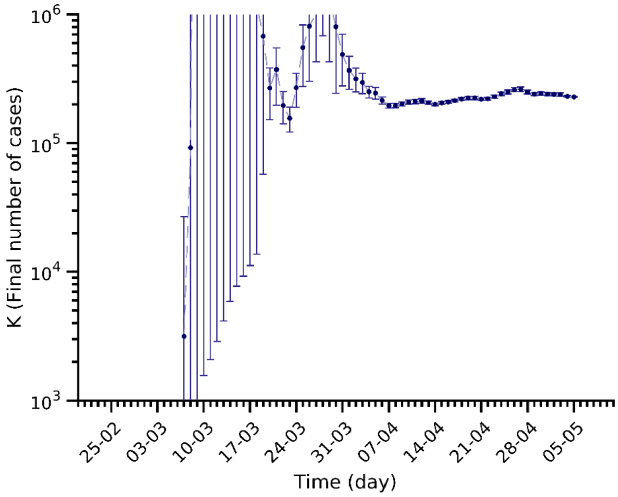


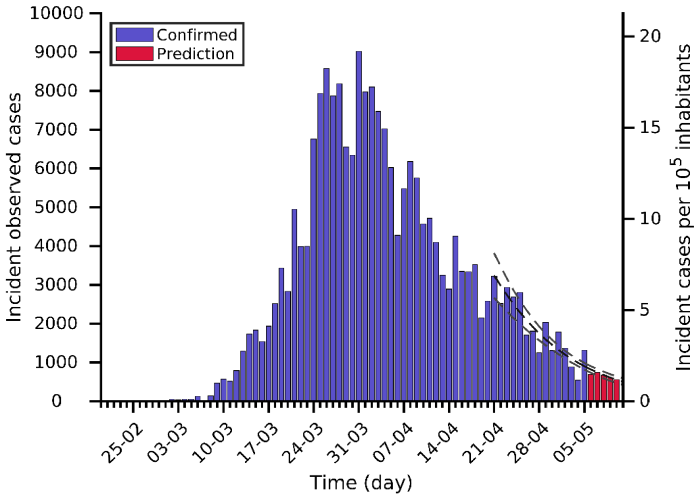
Spain 05-05-2020. Population: 47.0M. Current cumulated incidence: 466/10^5

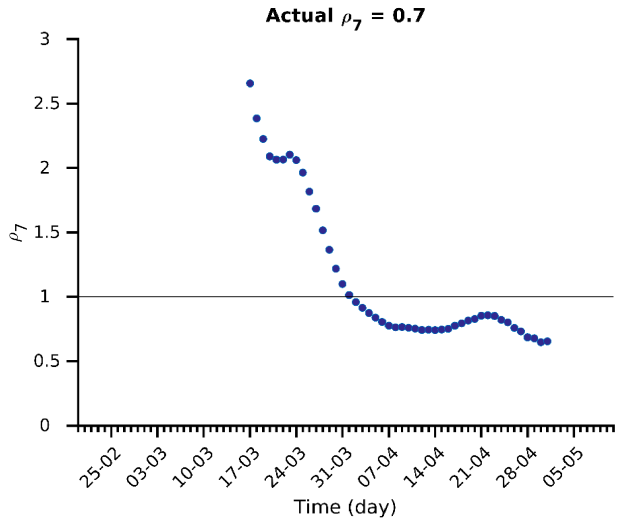


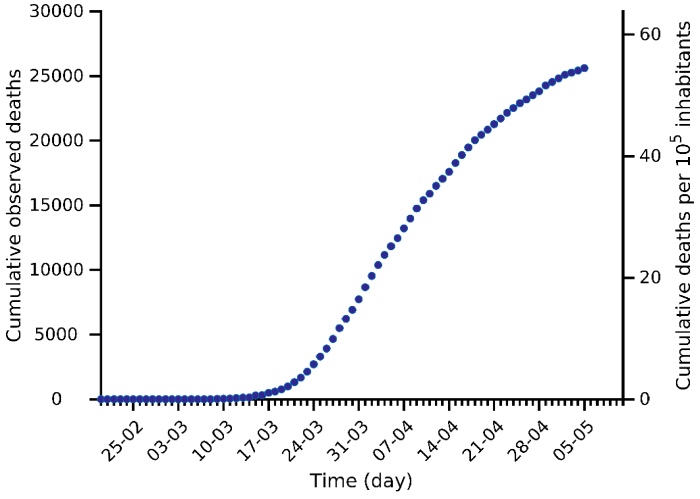


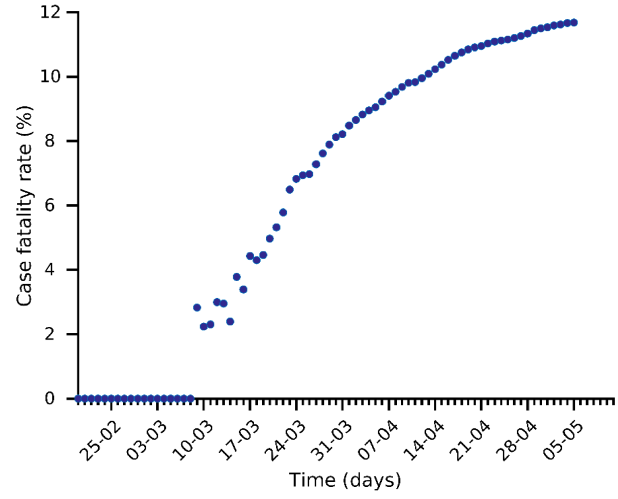




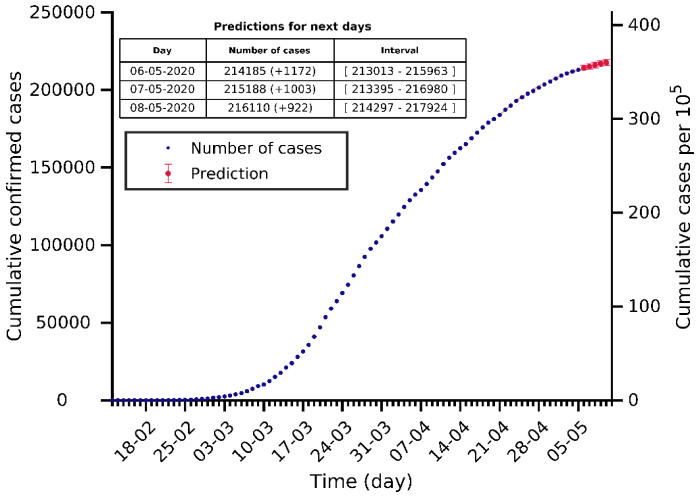


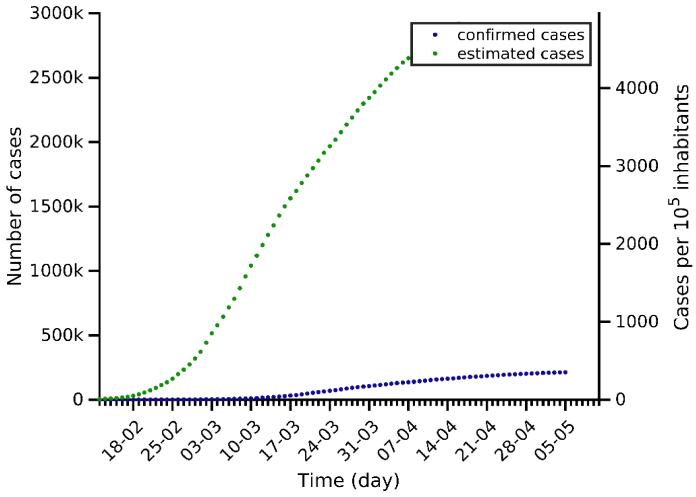


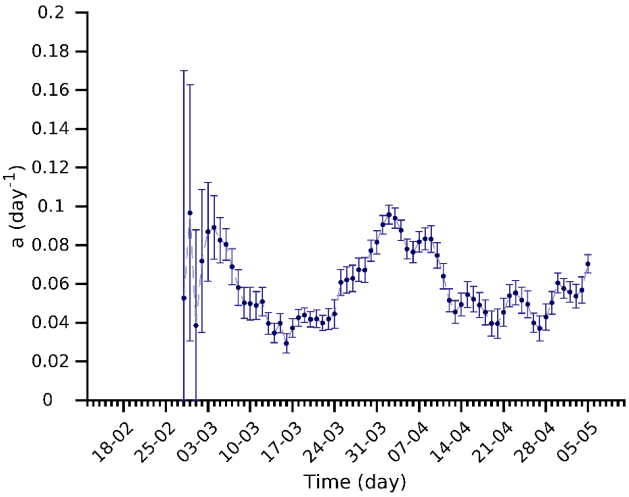


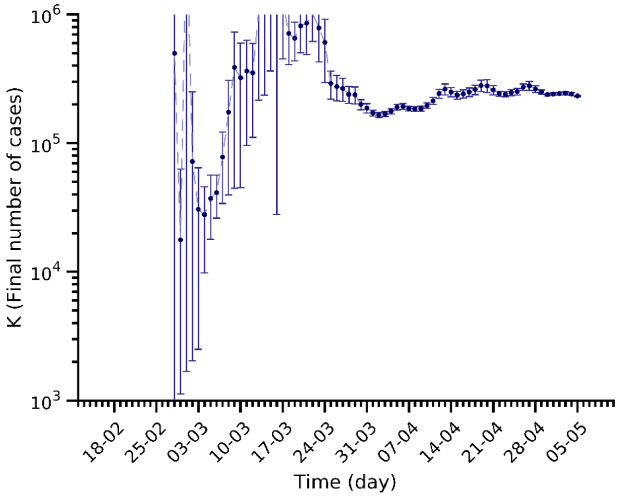


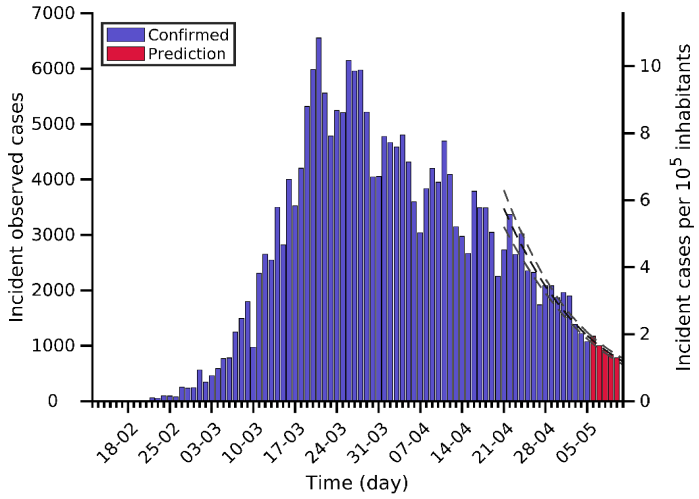
Italy 05-05-2020. Population: 60.5M. Current cumulated incidence: 352/10^5

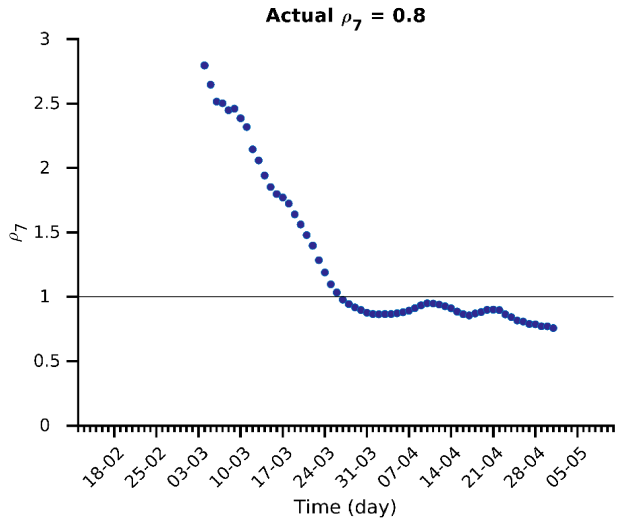


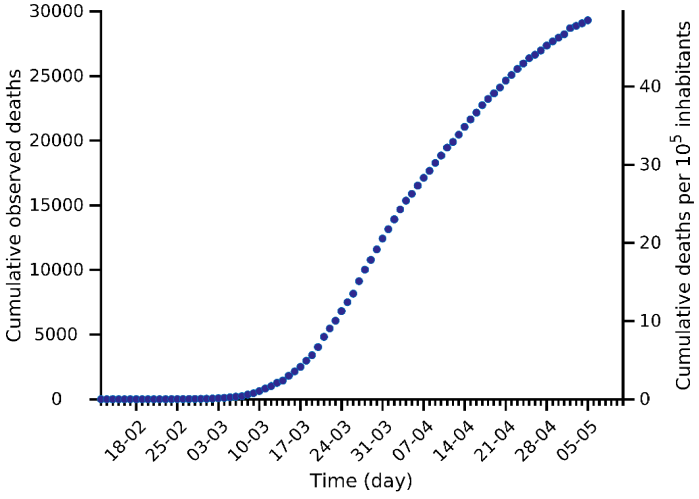


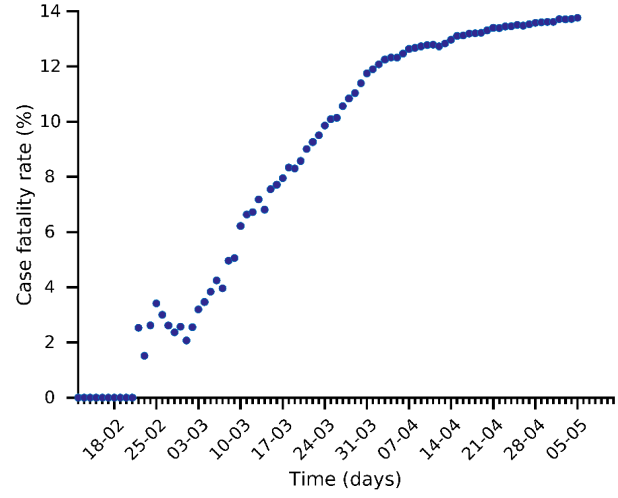




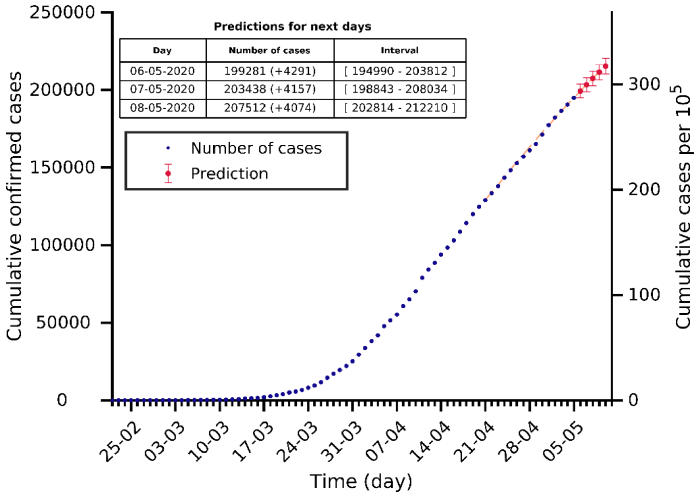


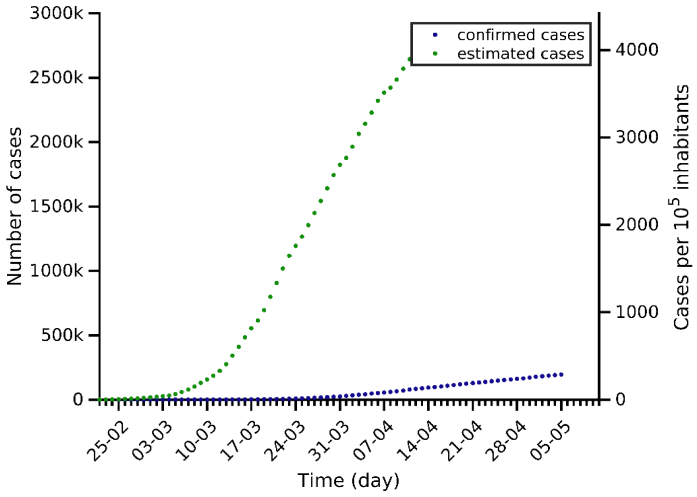


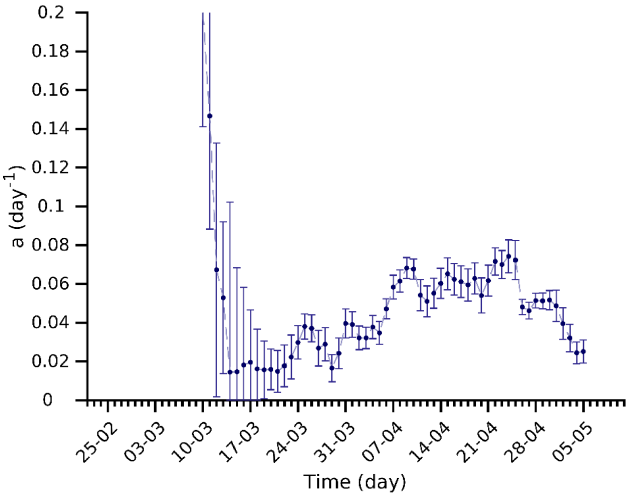


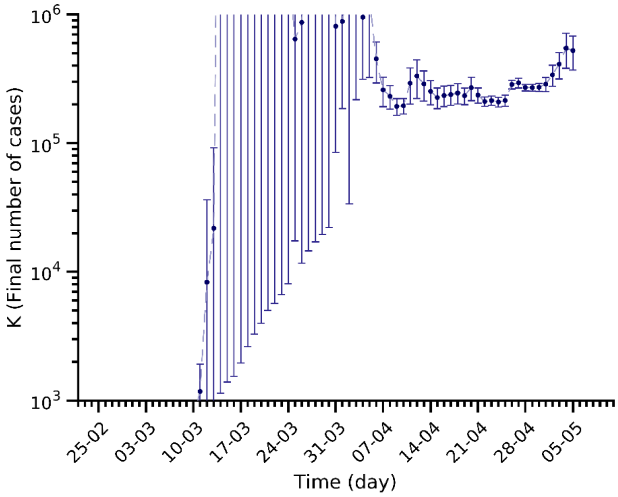


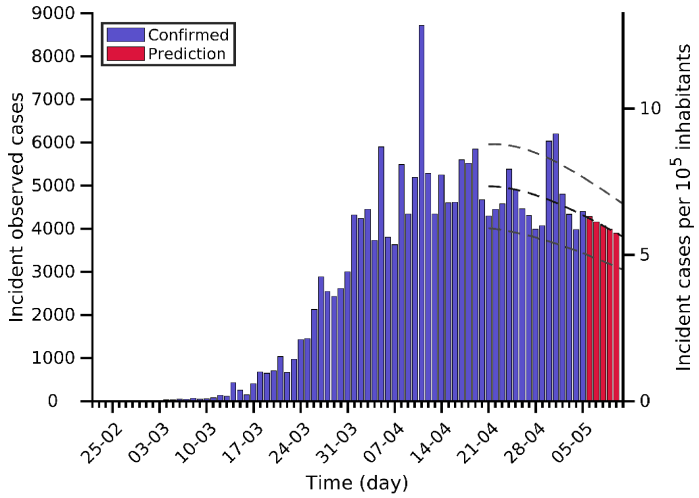
UK 05-05-2020. Population: 67.9M. Current cumulated incidence: $287/10^5$

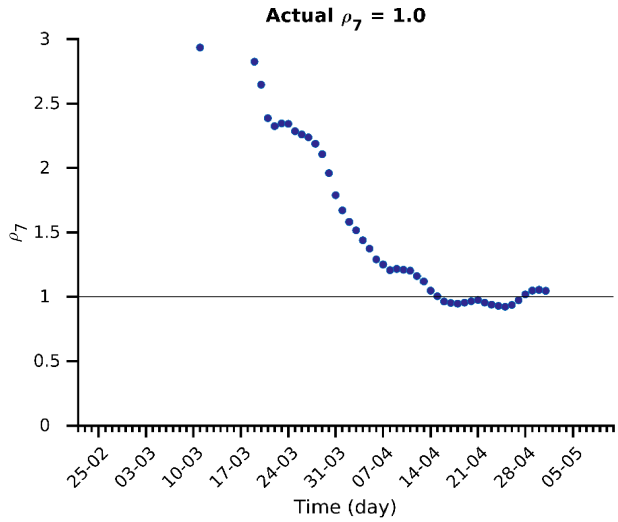


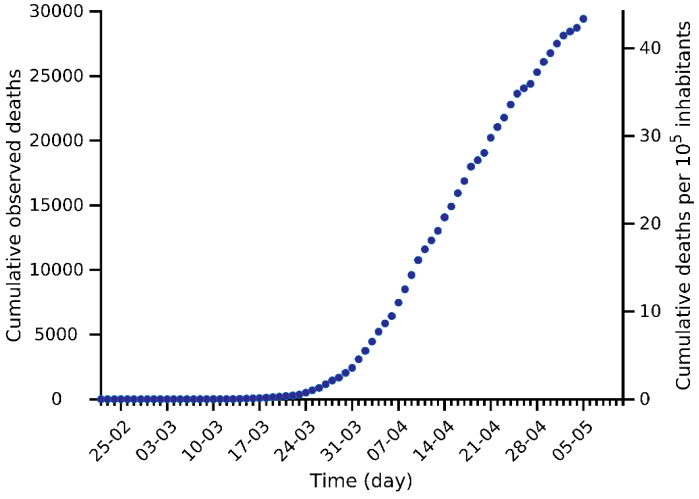


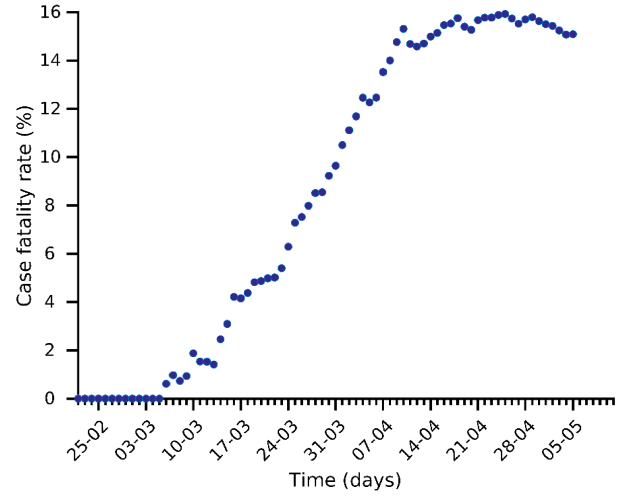




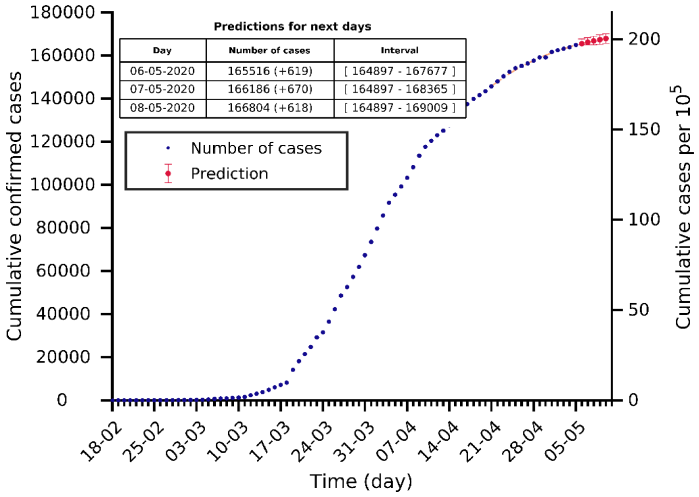


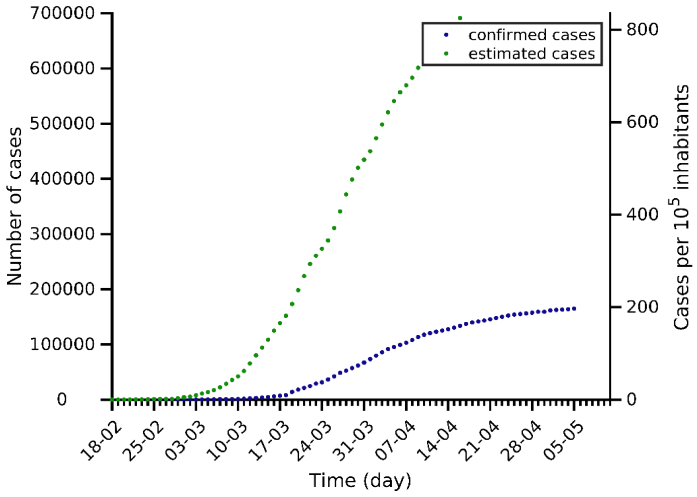


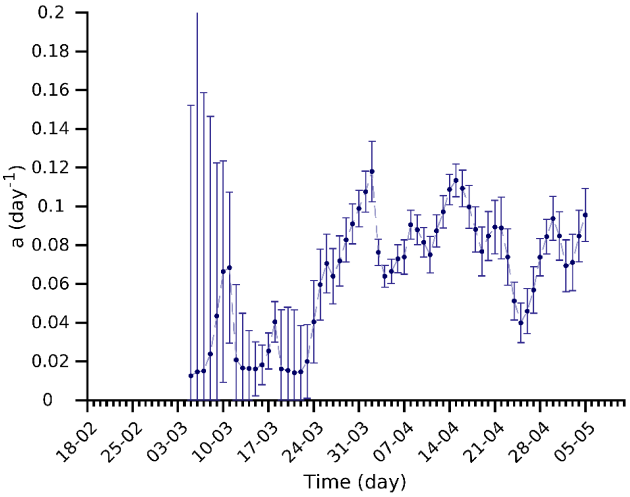


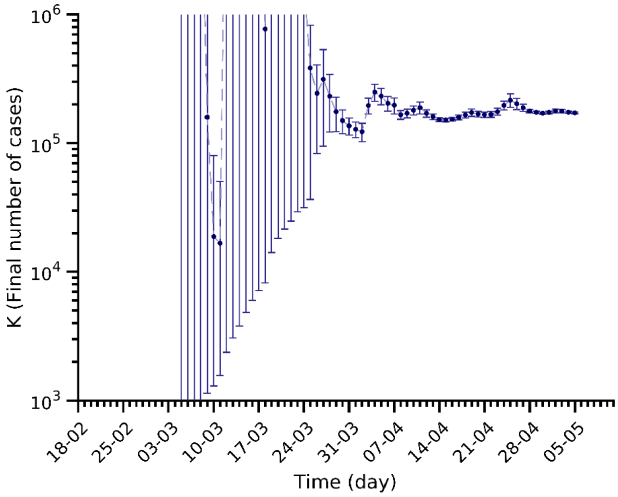


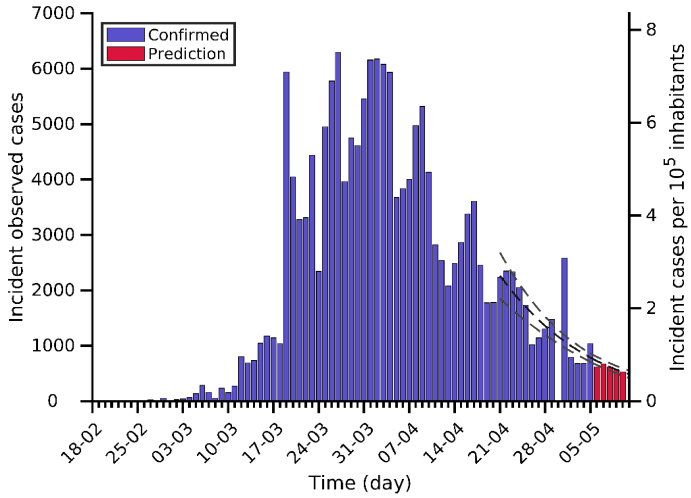
Germany 05-05-2020. Population: 83.8M. Current cumulated incidence: 197/10^5

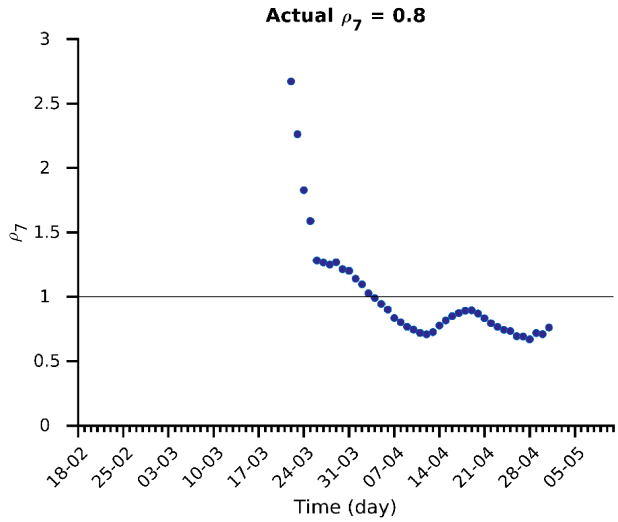


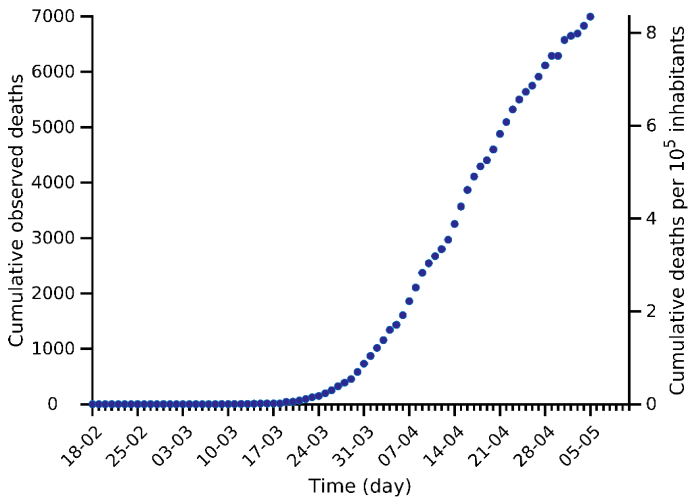


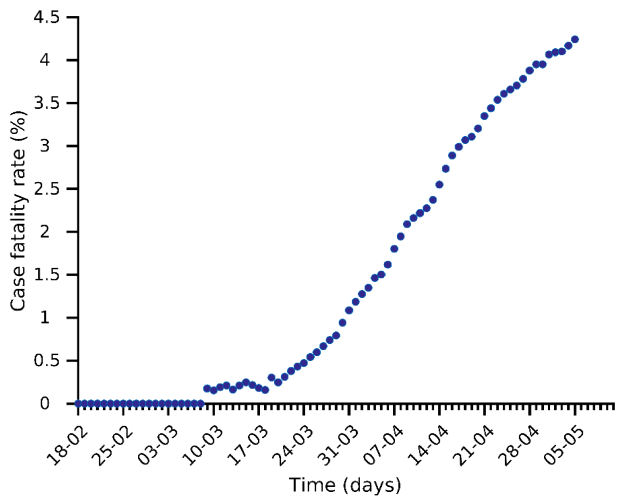




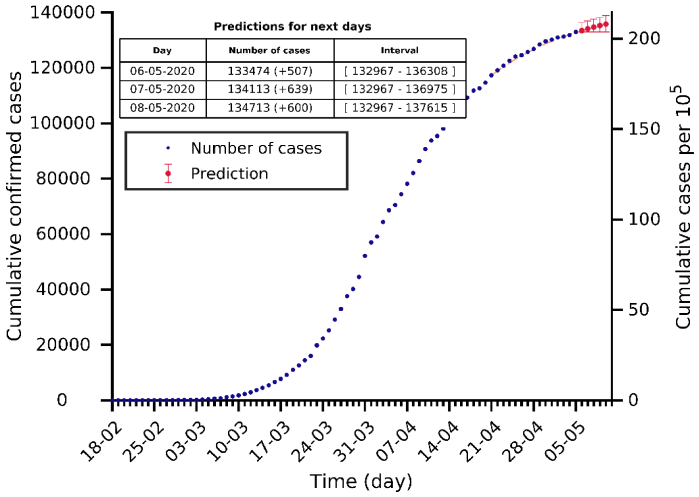


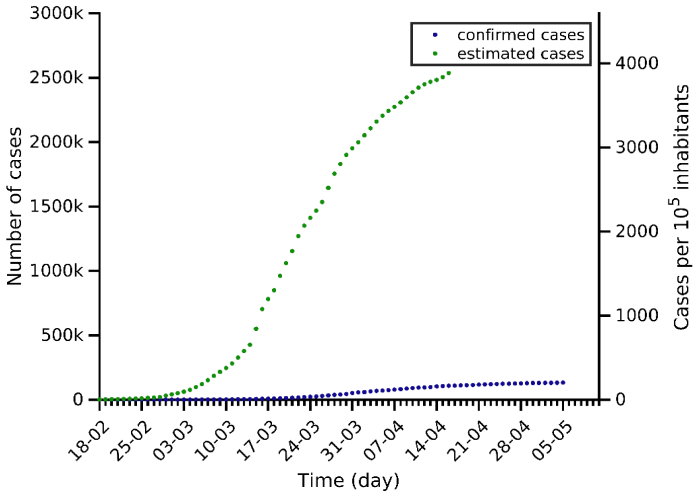


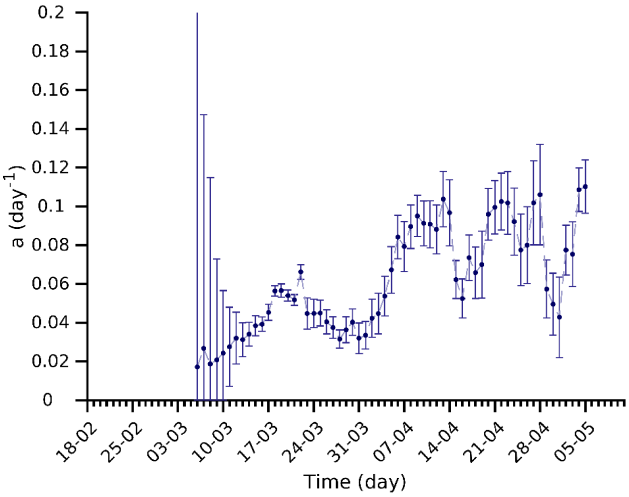


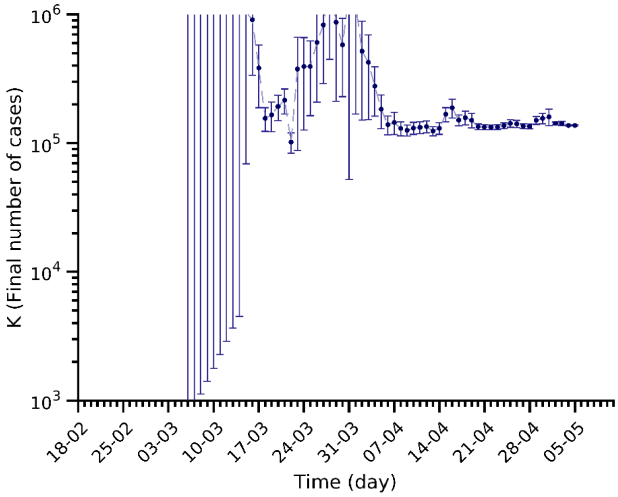


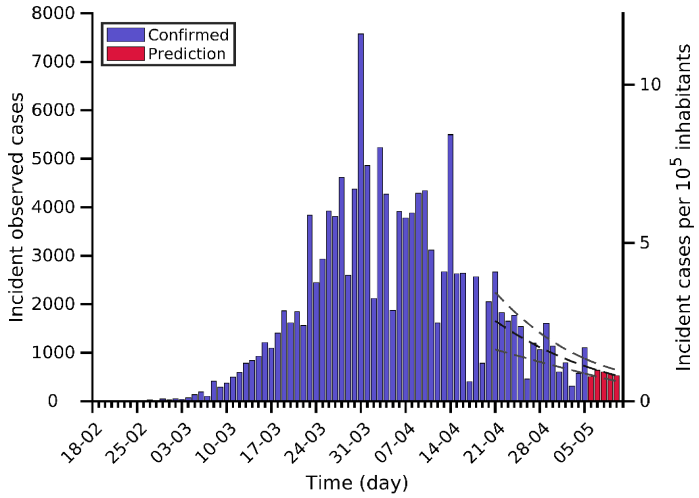
France 05-05-2020. Population: 65.3M. Current cumulated incidence: 204/10^5

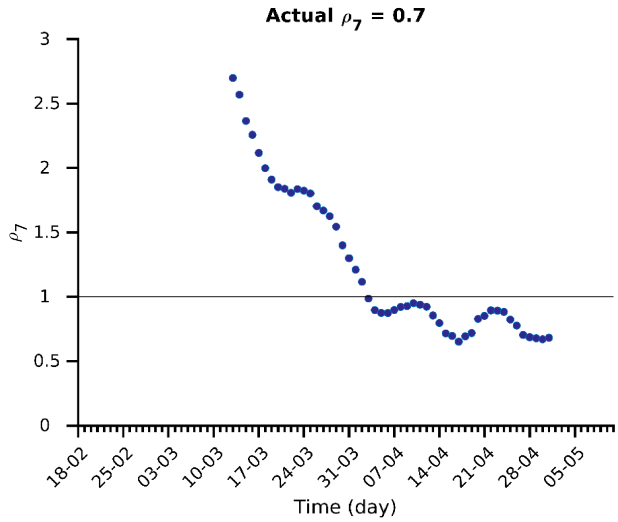


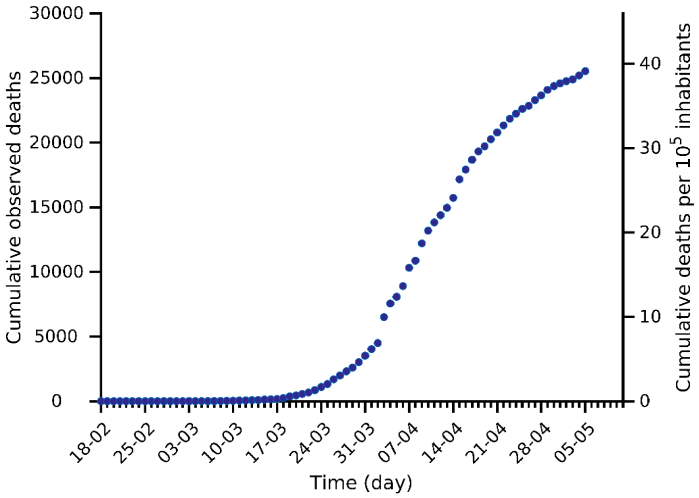


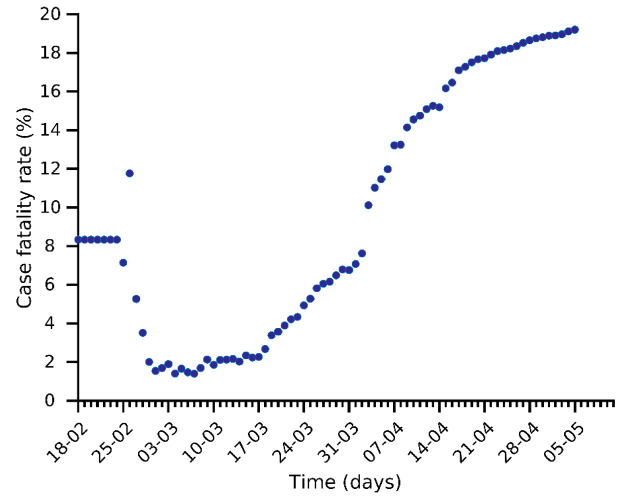




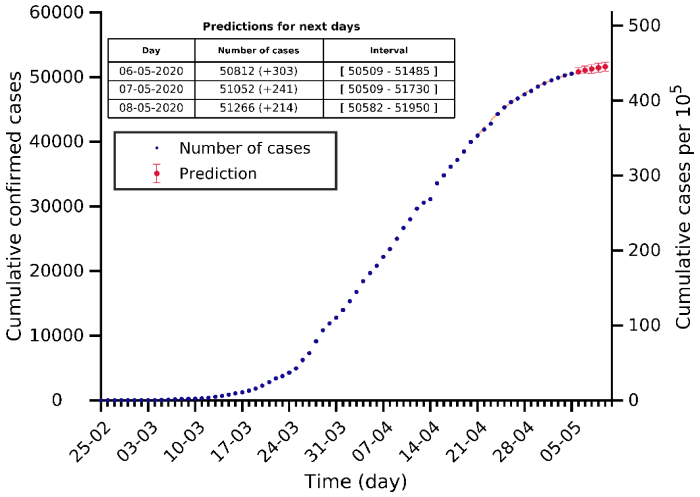


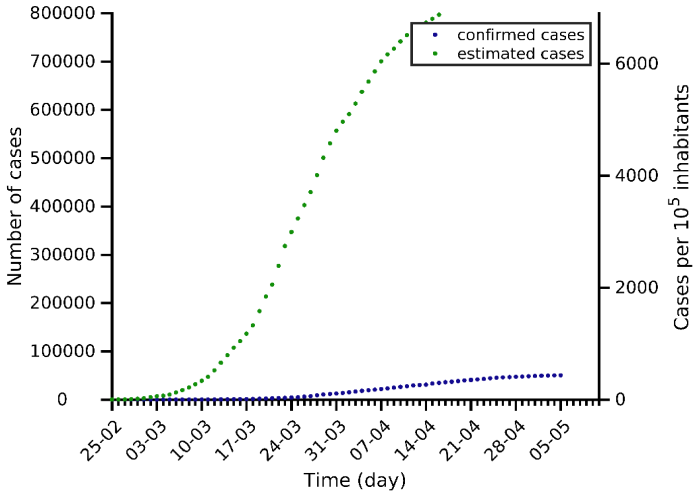


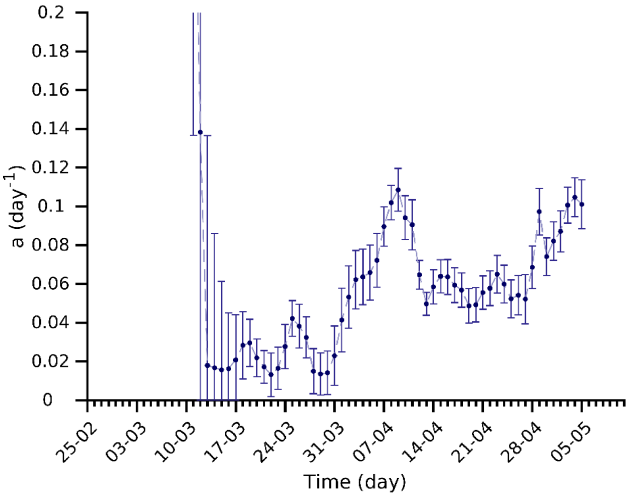


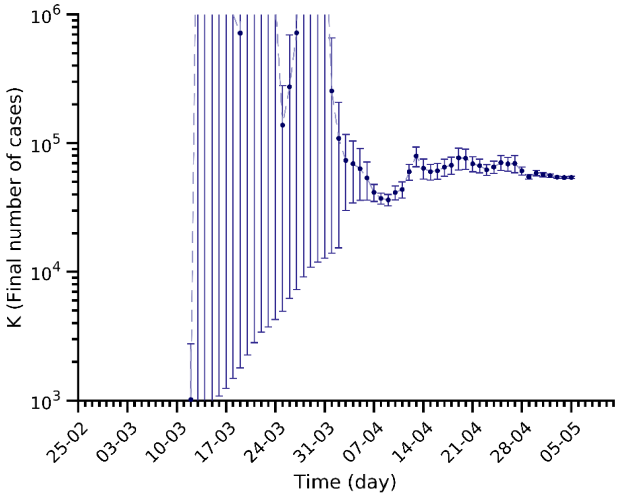


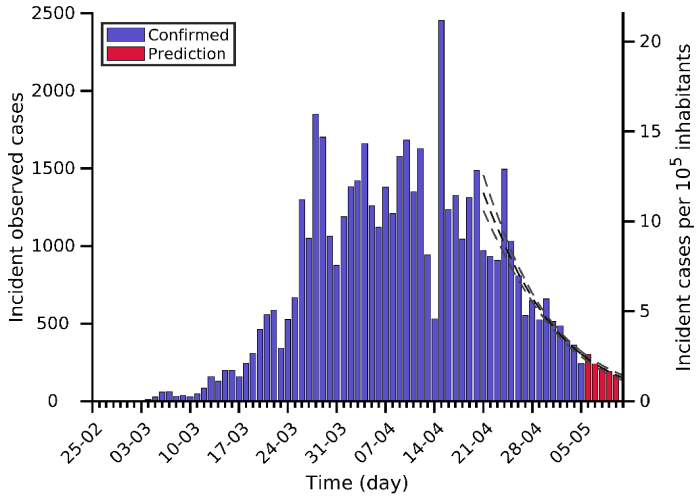
Belgium 05-05-2020. Population: 11.6M. Current cumulated incidence: 436/10^5

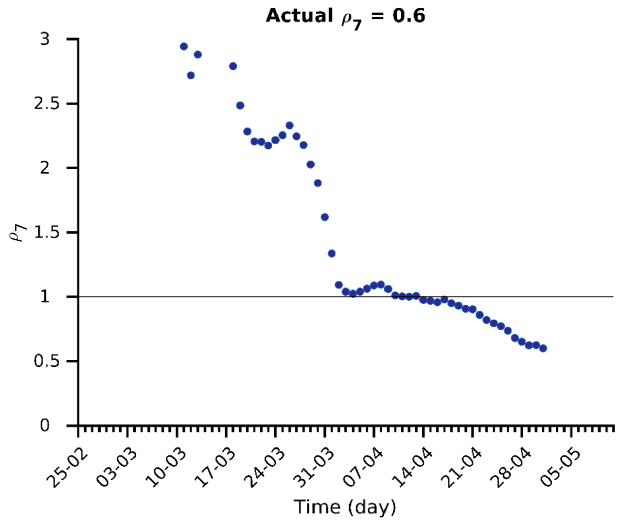


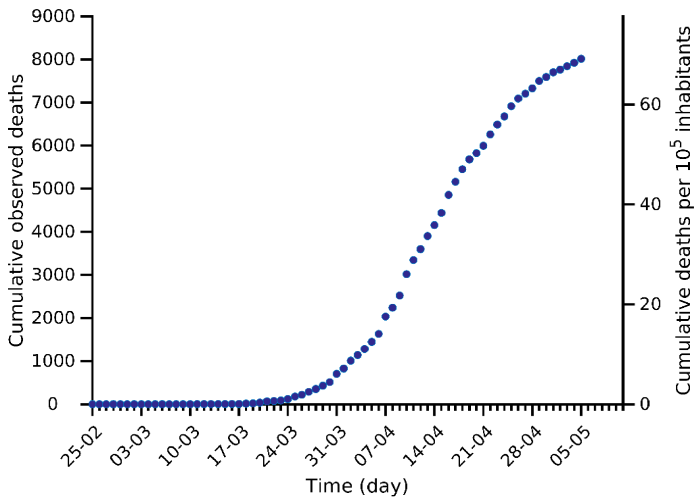


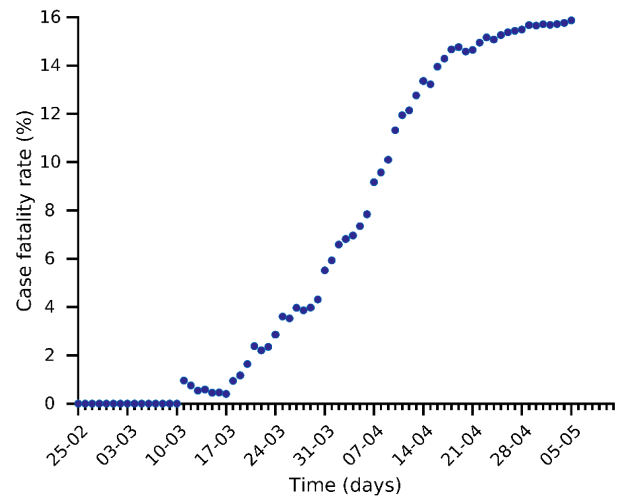




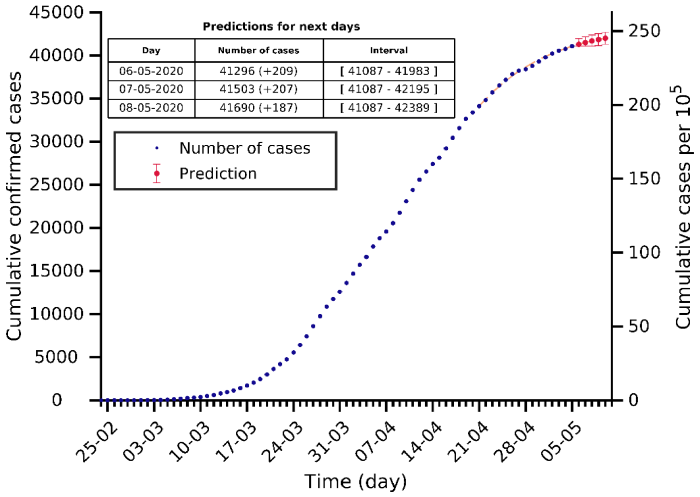


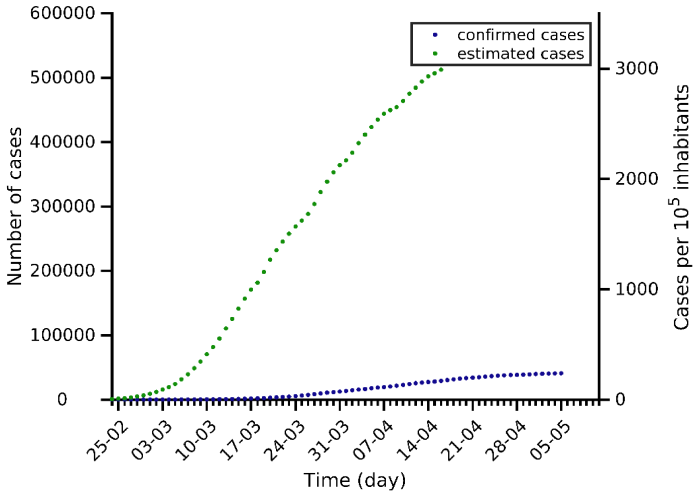


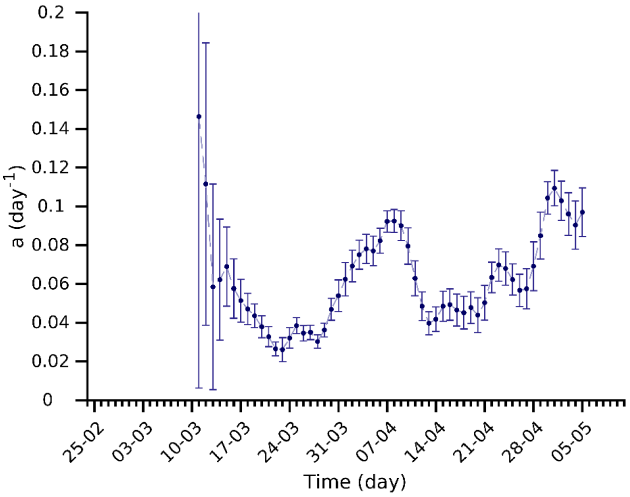


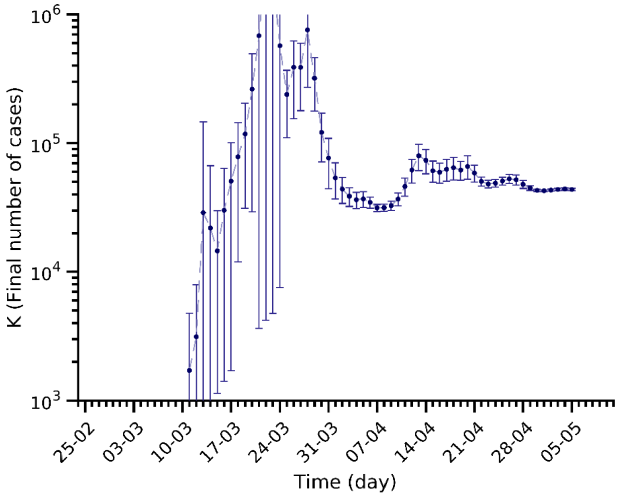


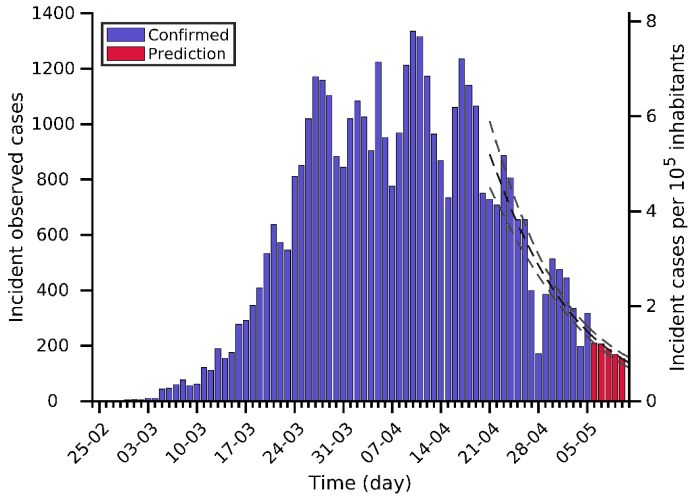
Netherlands 05-05-2020. Population: 17.1M. Current cumulated incidence: 240/10^5

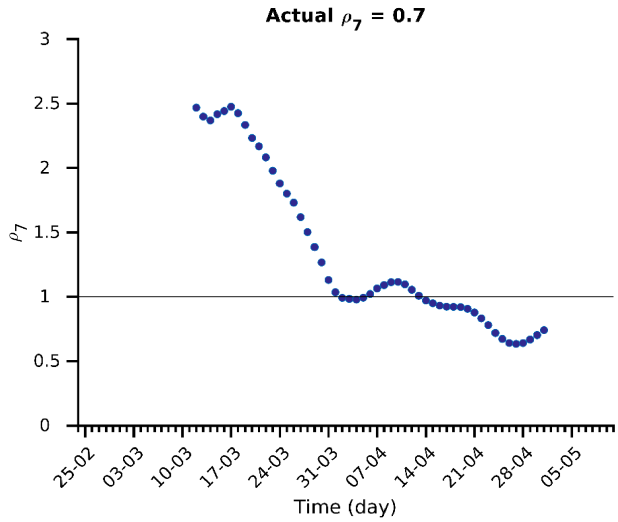


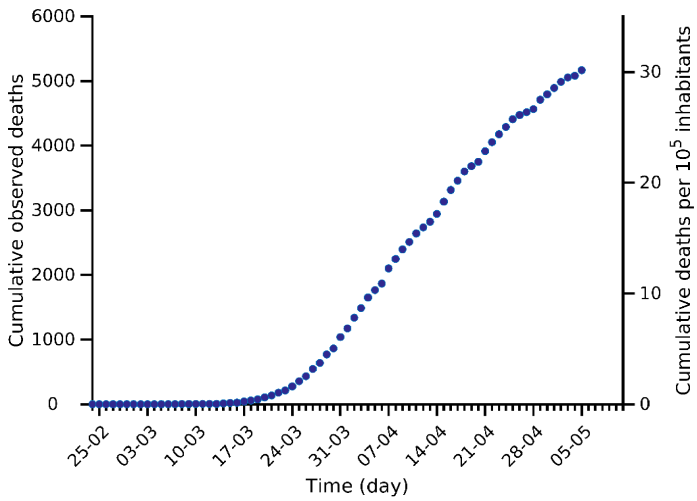


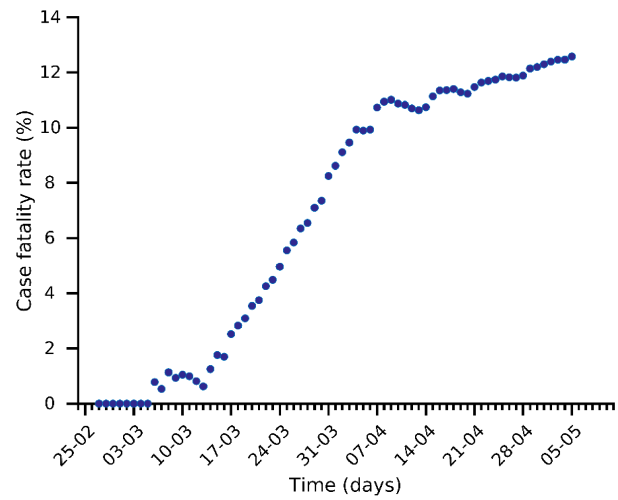




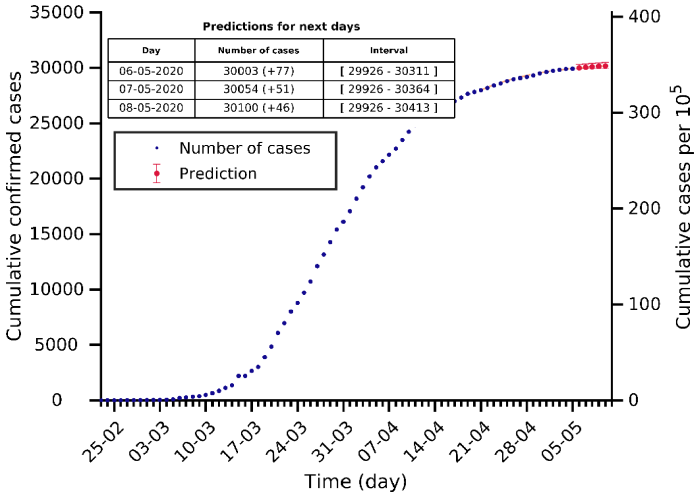


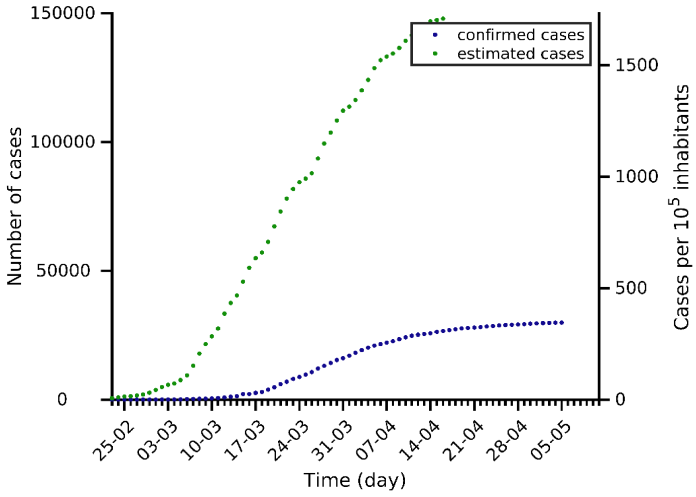


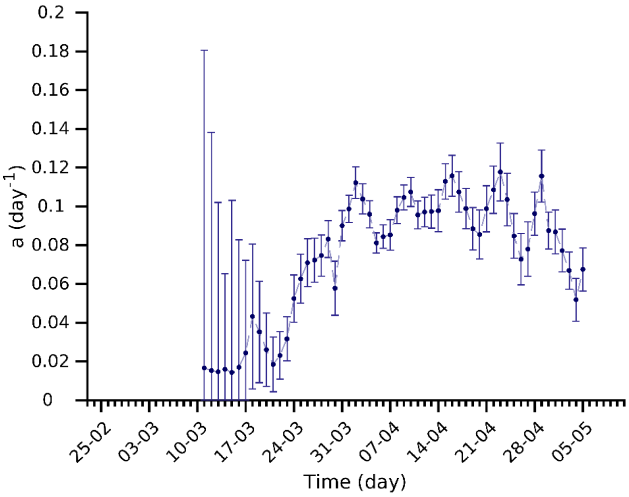


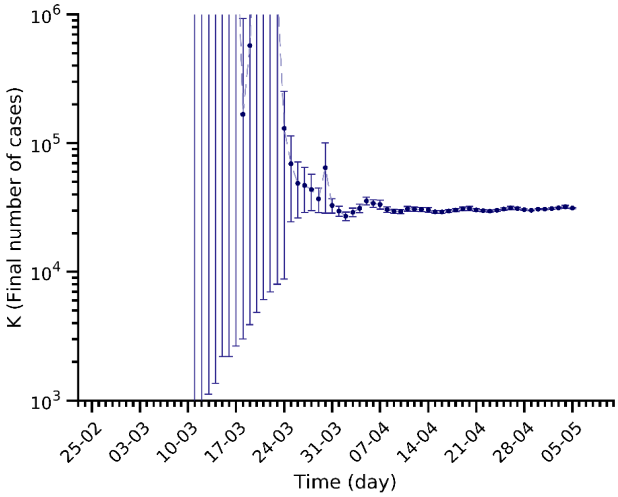


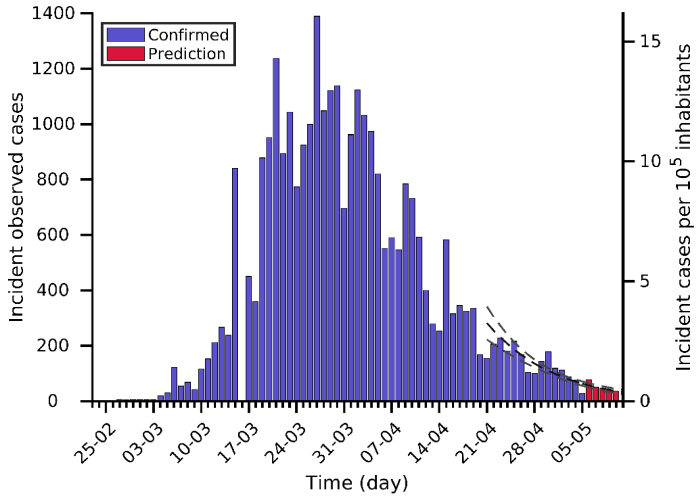
Switzerland 05-05-2020. Population: 8.7M. Current cumulated incidence: 346/10^5

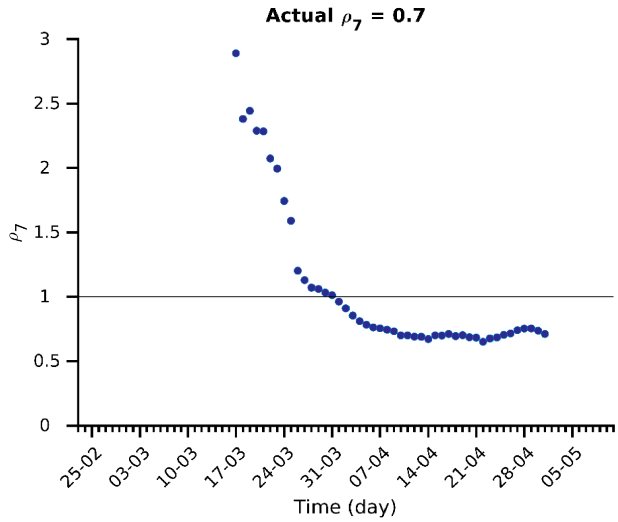


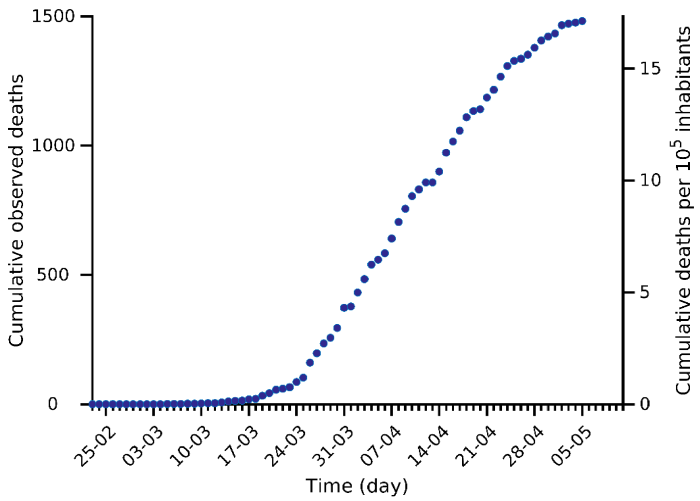


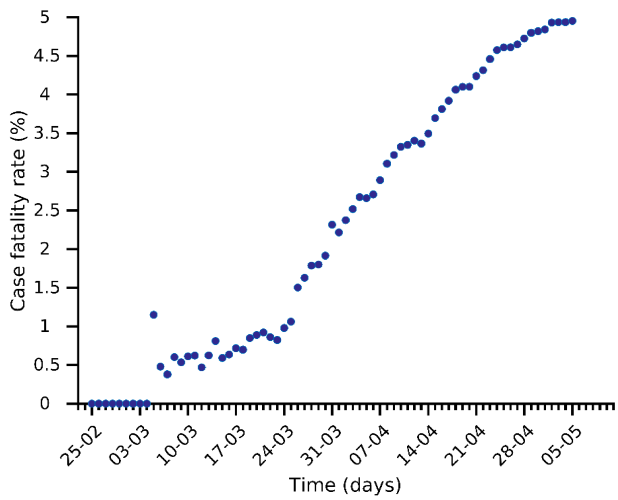




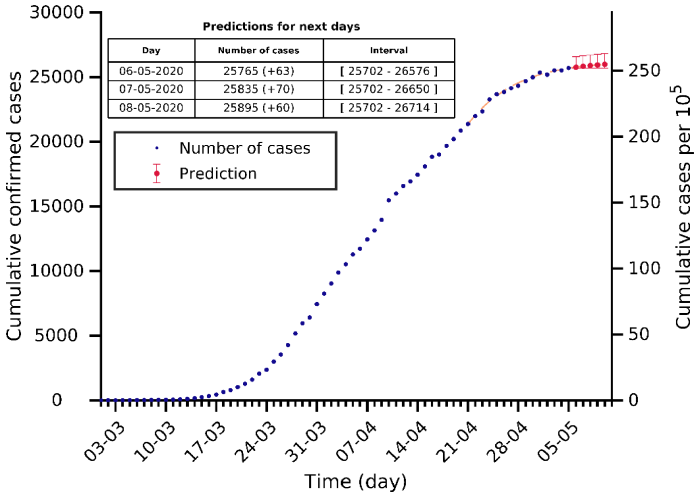


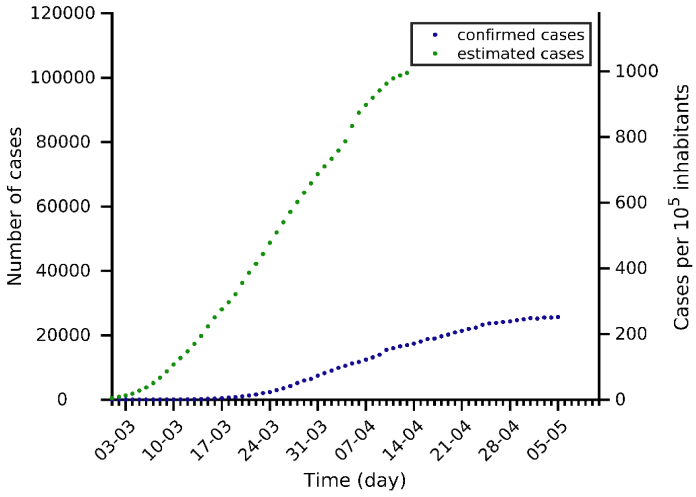


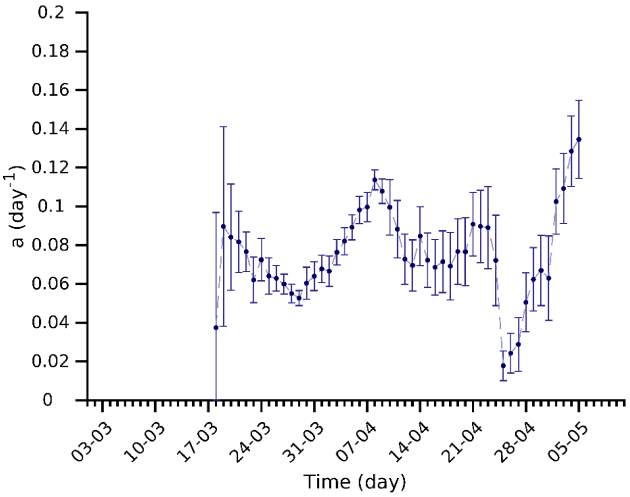


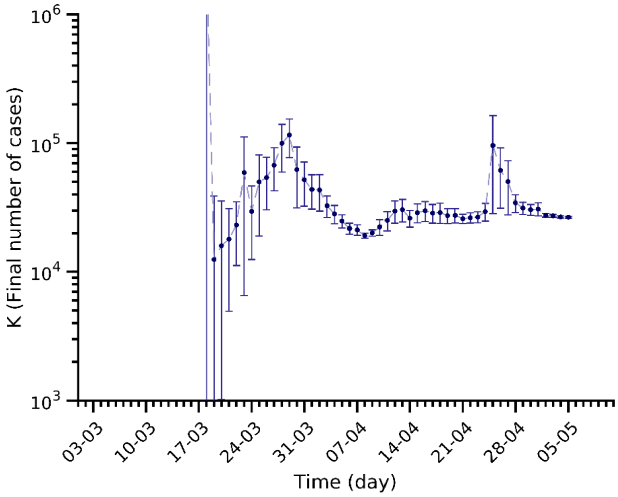


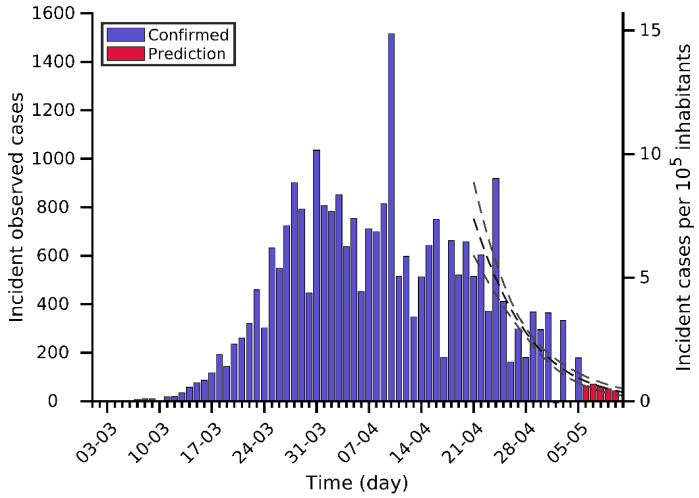
Portugal 05-05-2020. Population: 10.2M. Current cumulated incidence: 252/10⁵

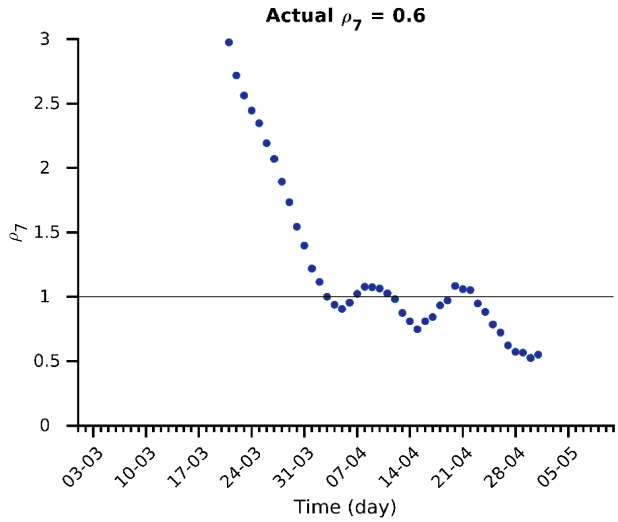


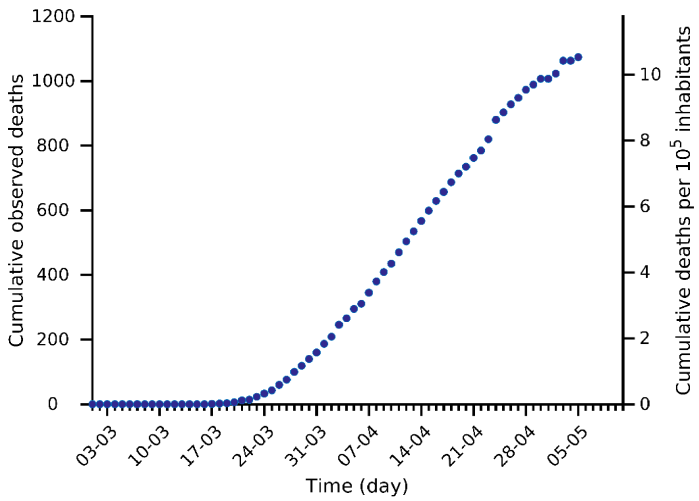


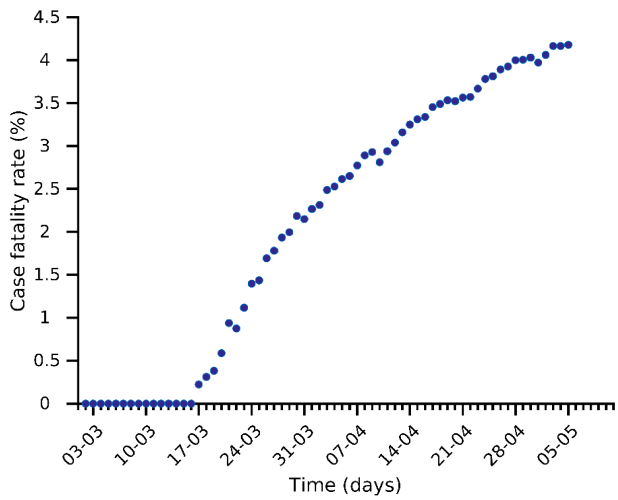




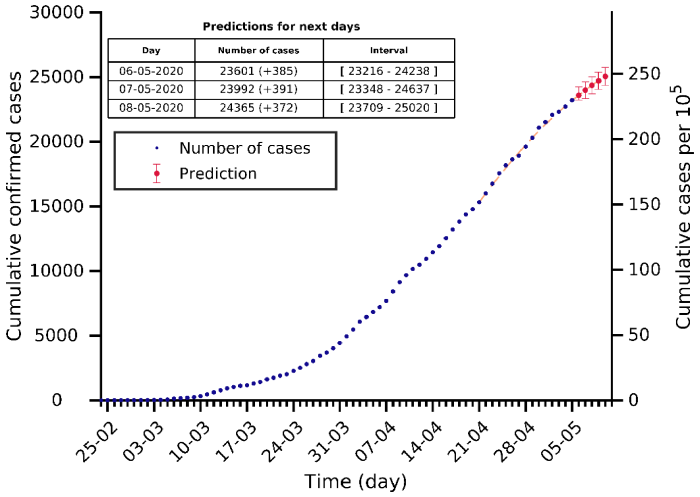


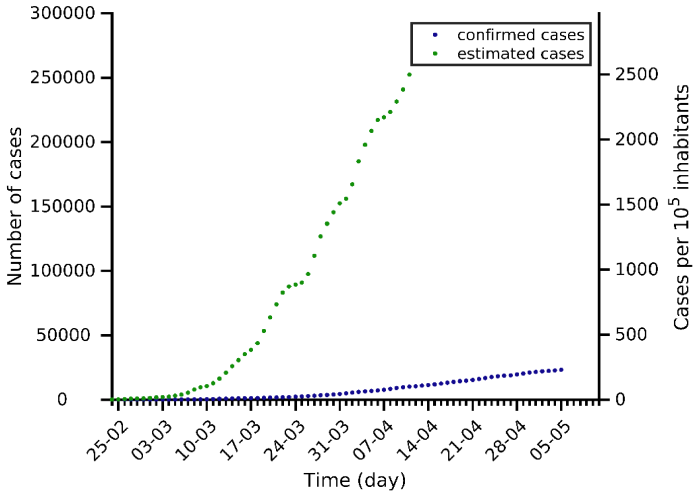


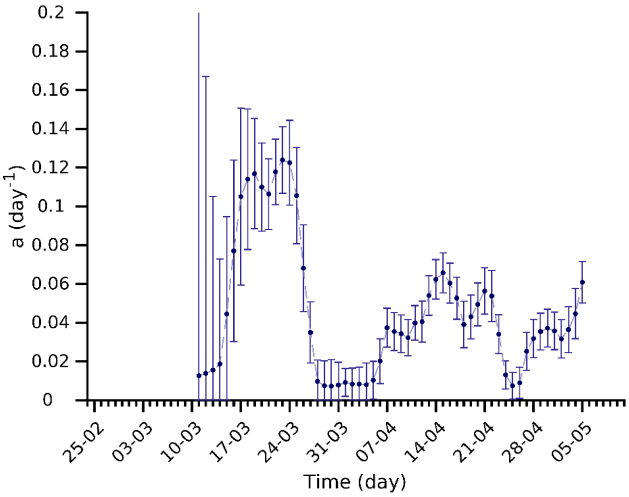


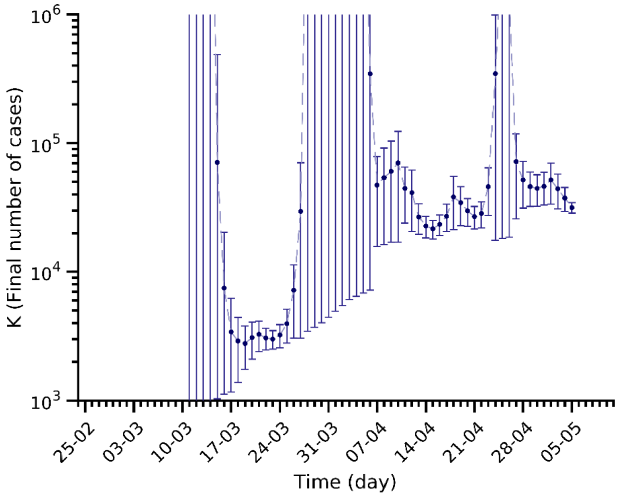


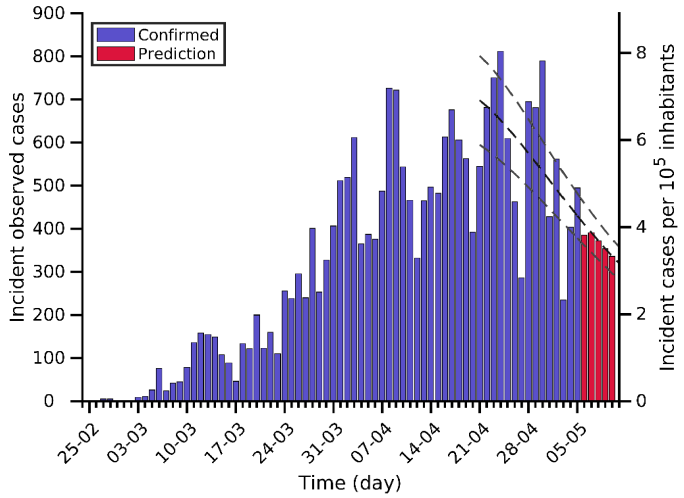
Sweden 05-05-2020. Population: 10.1M. Current cumulated incidence: 230/10^5

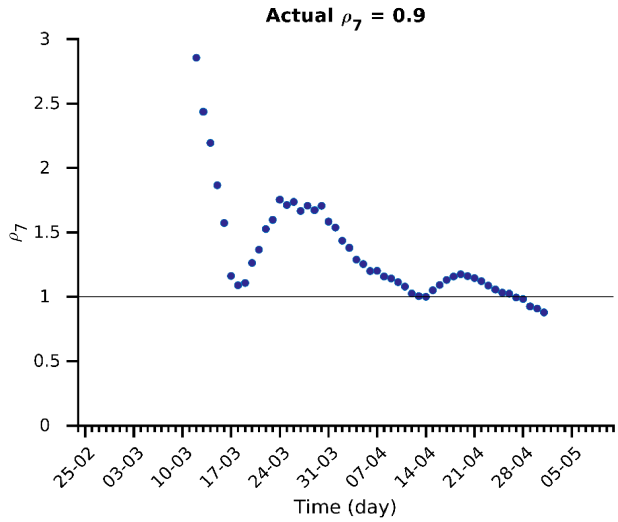


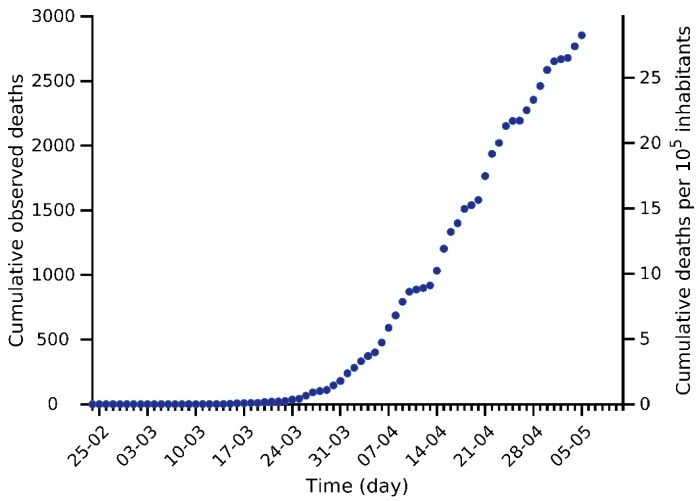


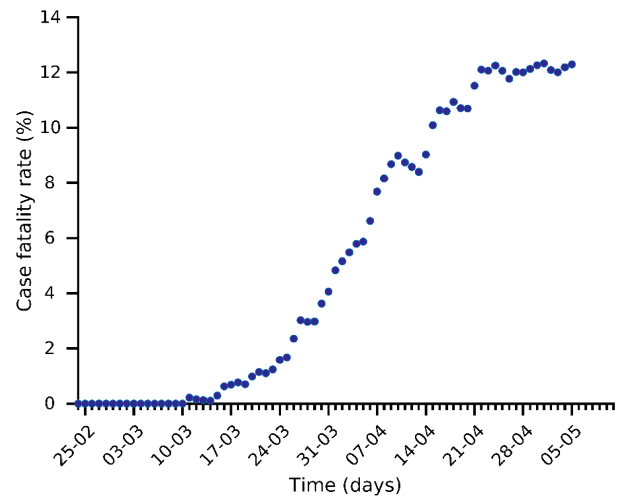




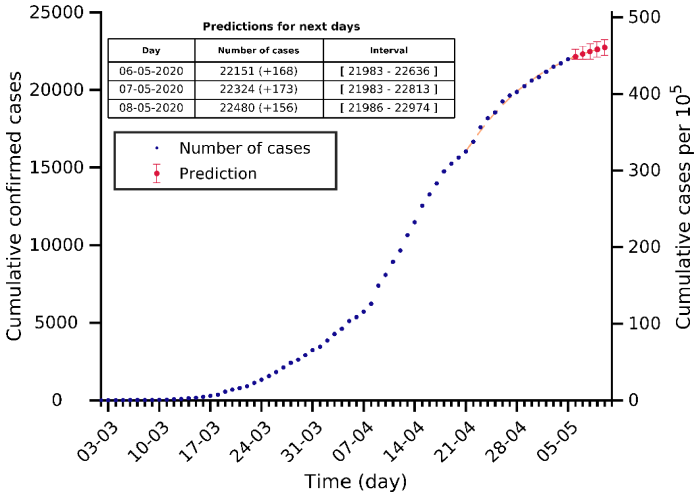


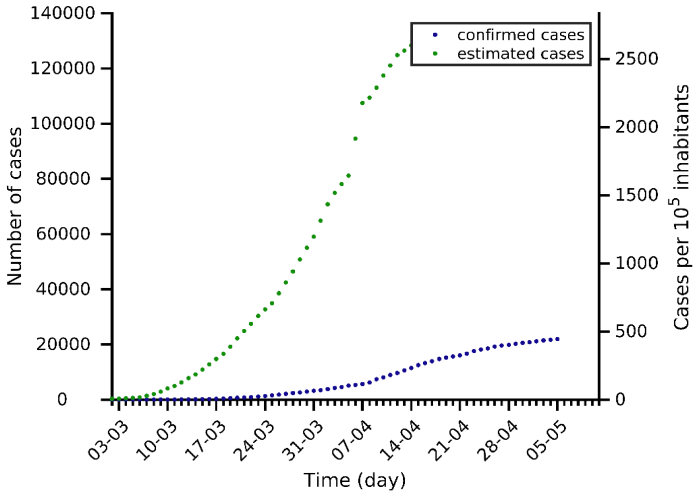


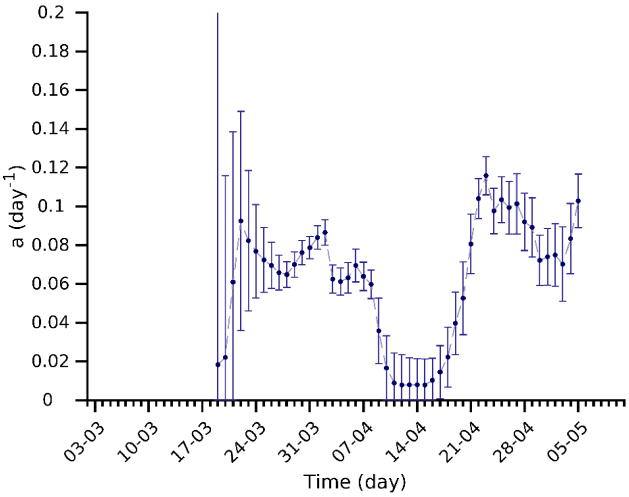


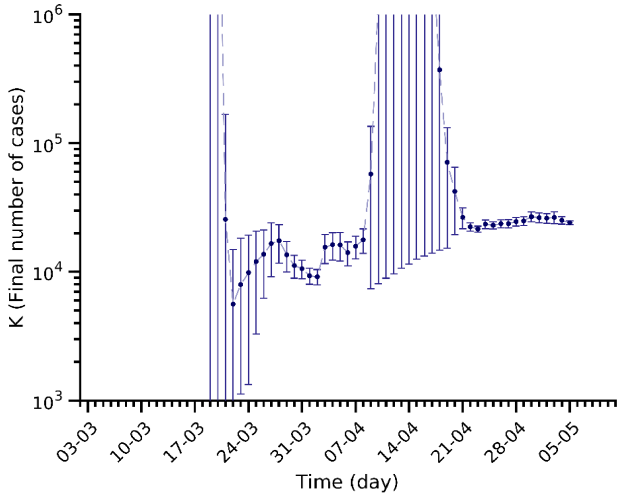


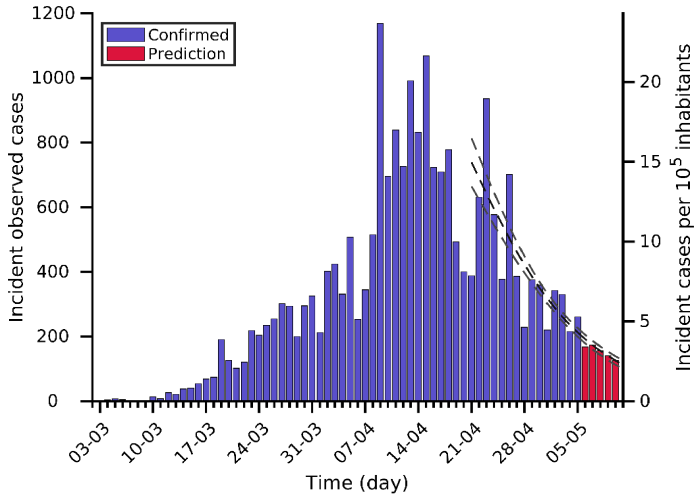
Ireland 05-05-2020. Population: 4.9M. Current cumulated incidence: 445/10^5

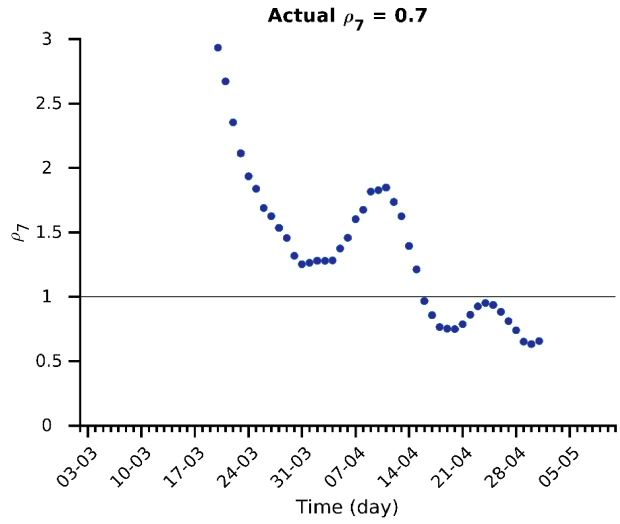


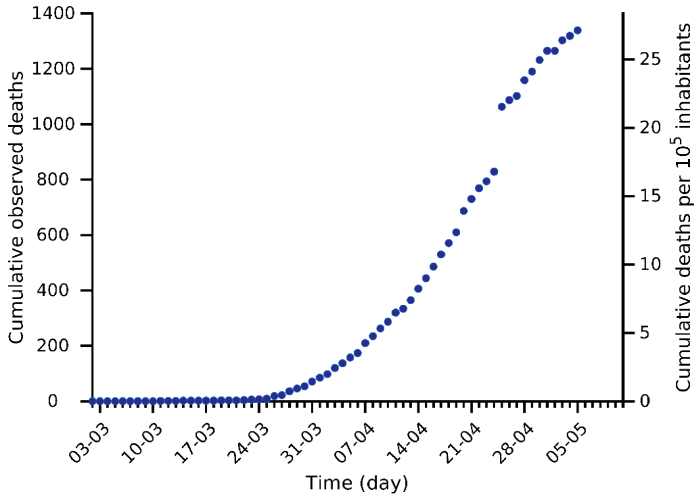


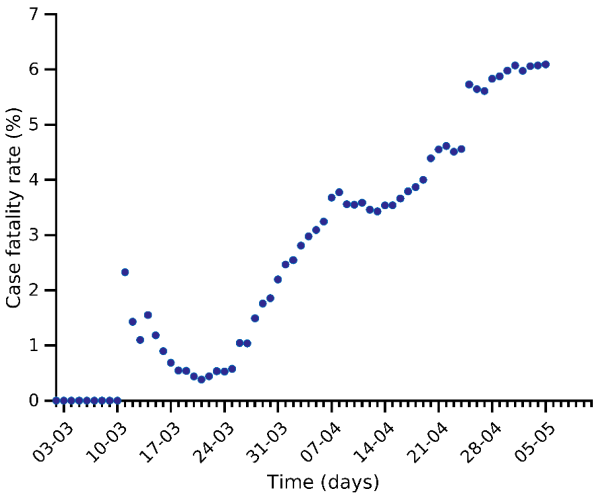




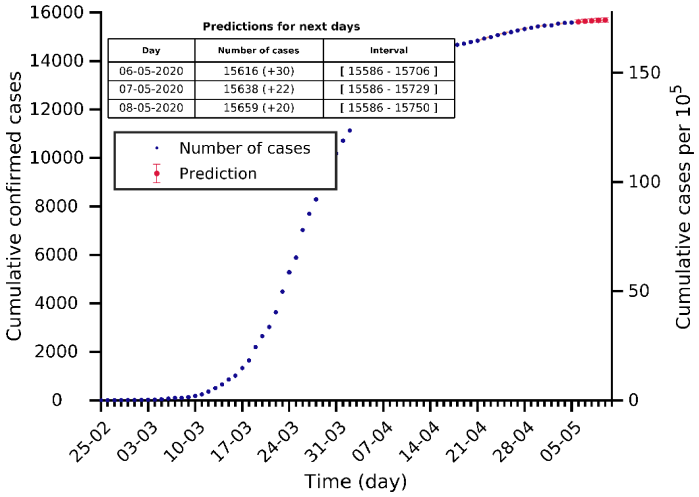


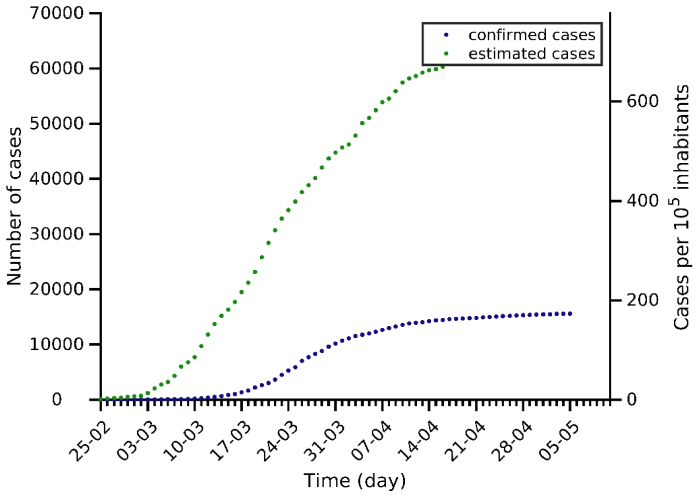


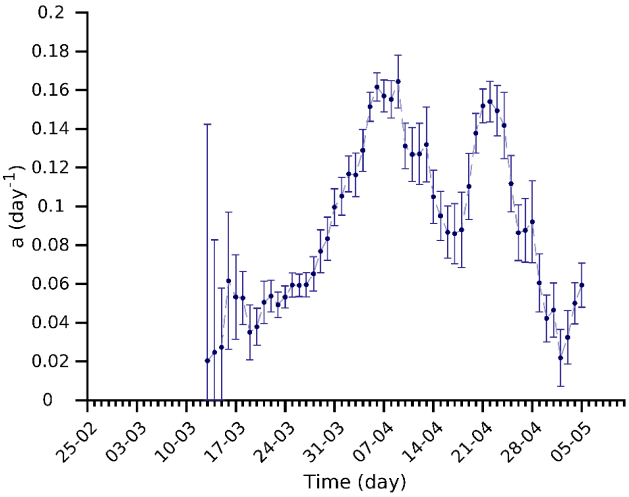


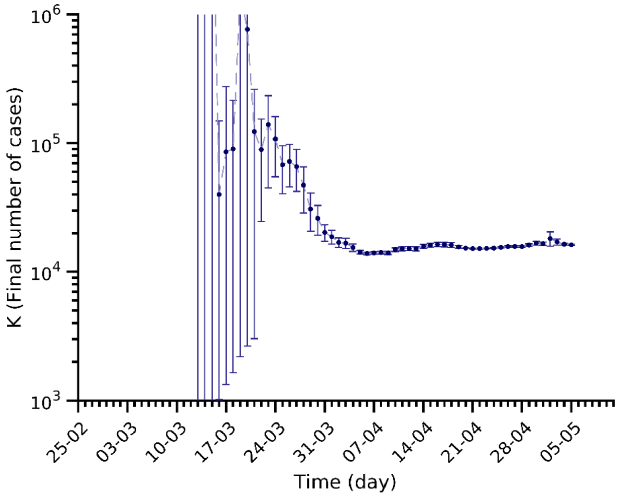


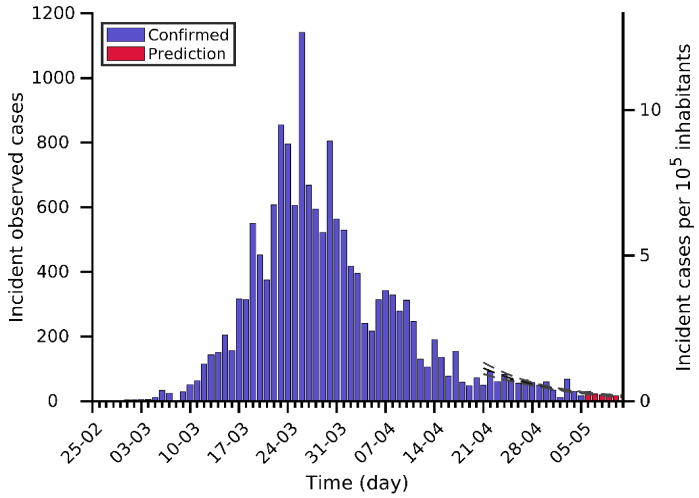
Austria 05-05-2020. Population: 9.0M. Current cumulated incidence: 173/10⁵

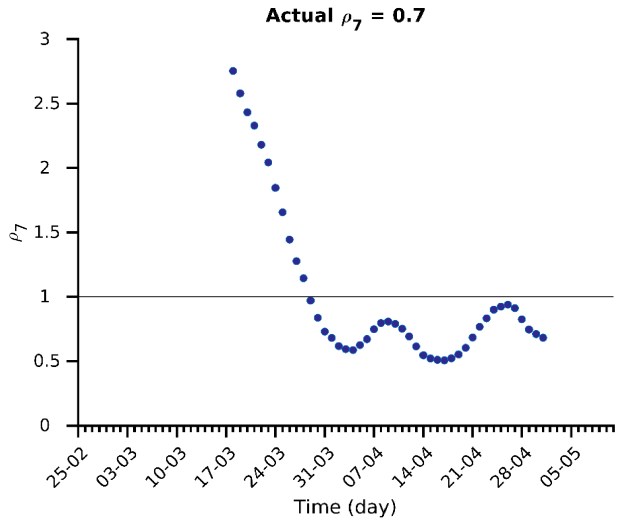


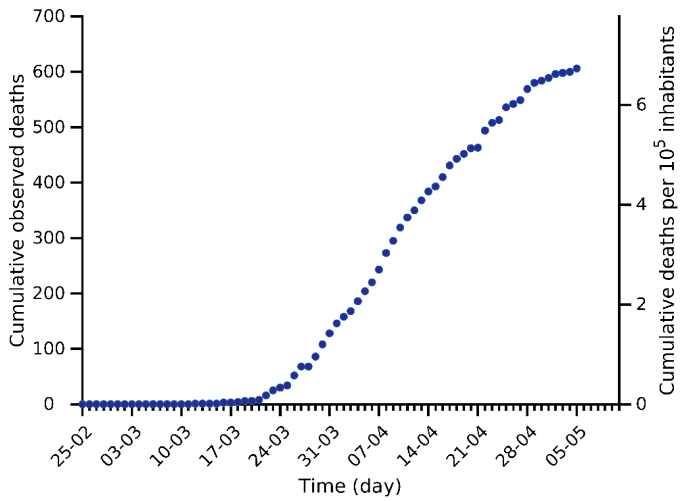


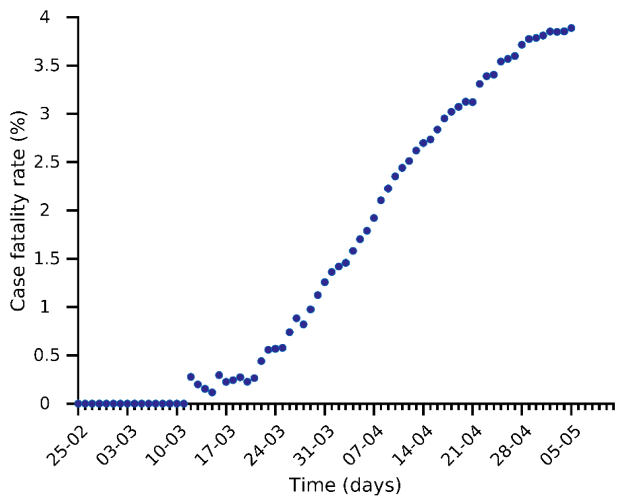




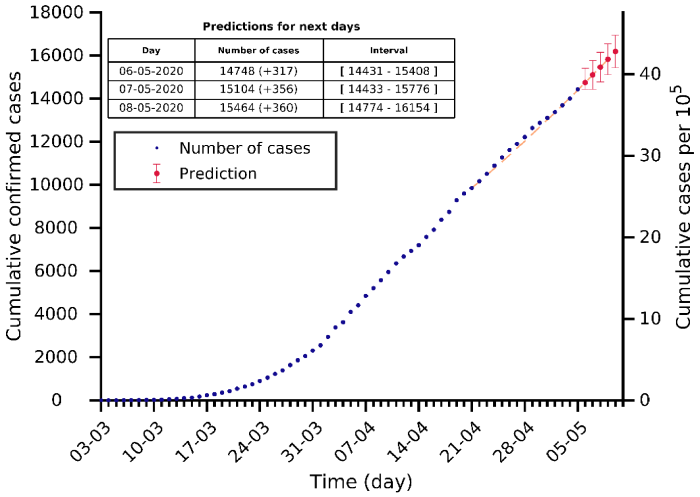


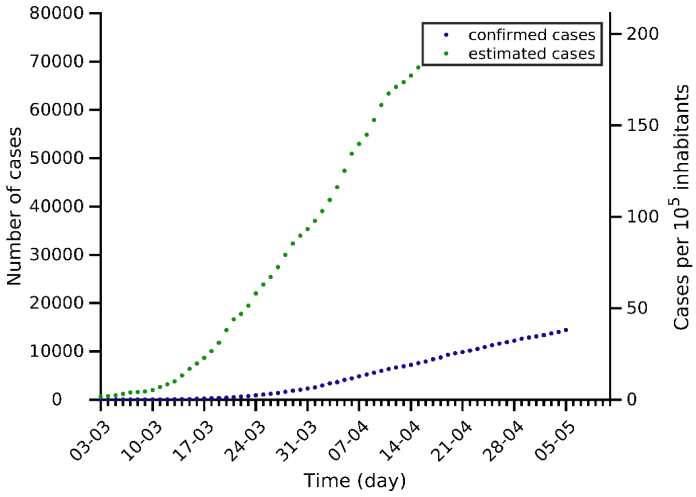


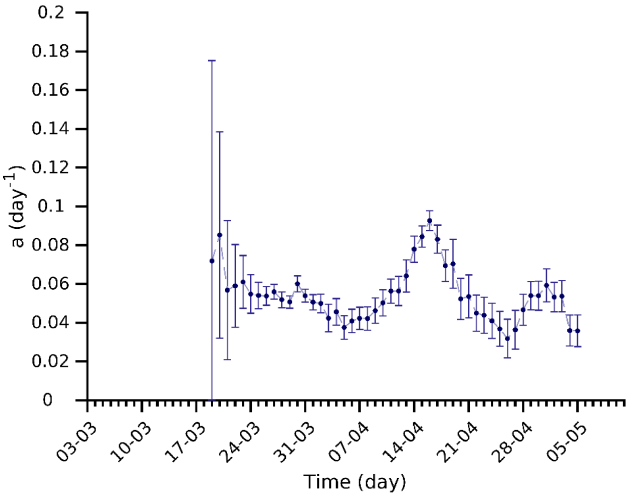


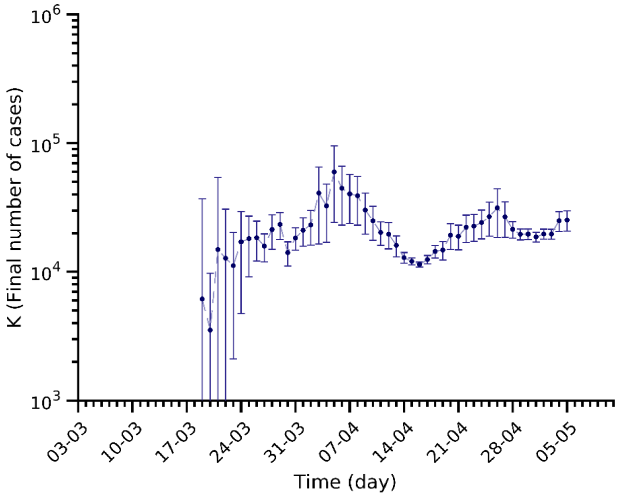


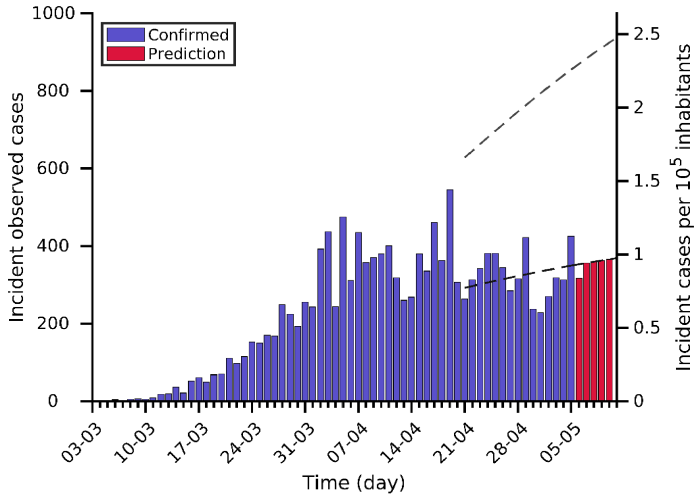
Poland 05-05-2020. Population: 37.8M. Current cumulated incidence: $38/10^5$

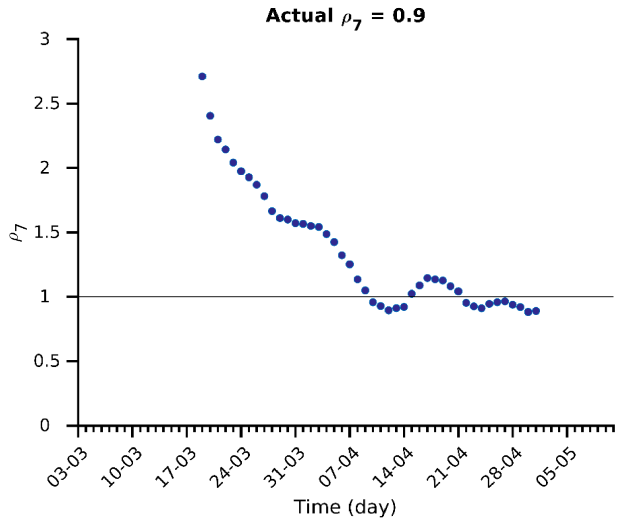


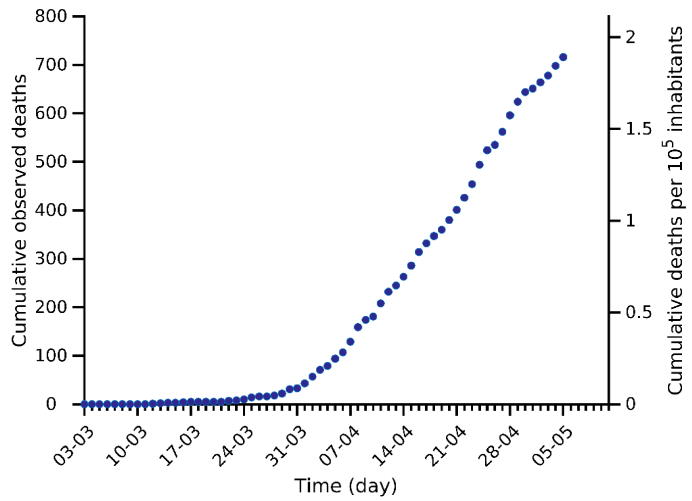


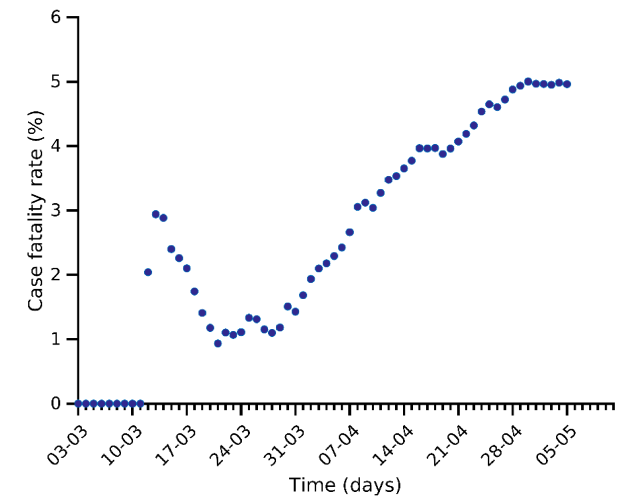




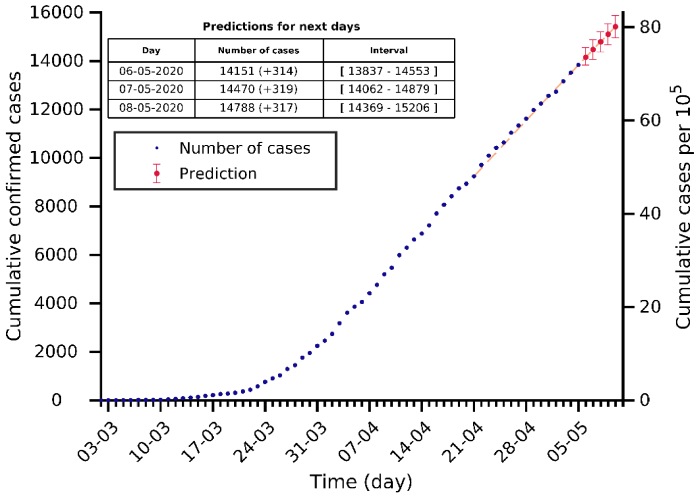


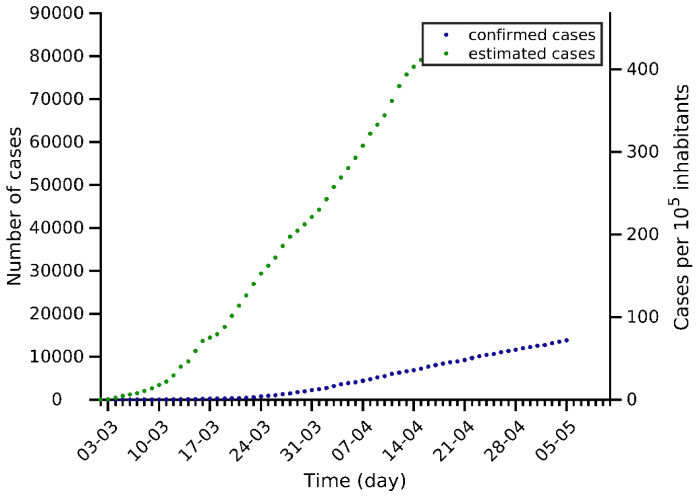


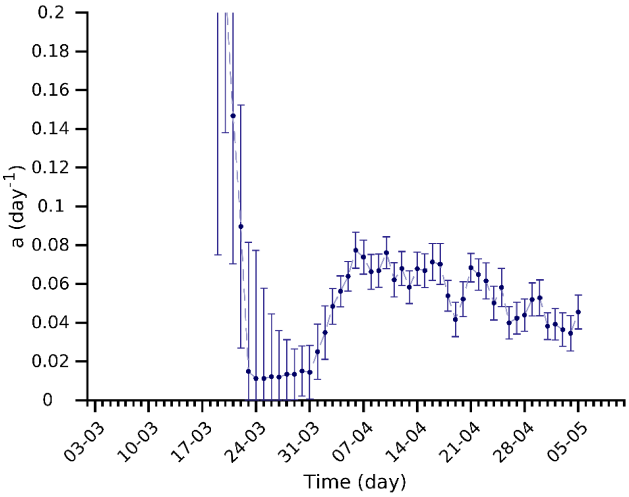


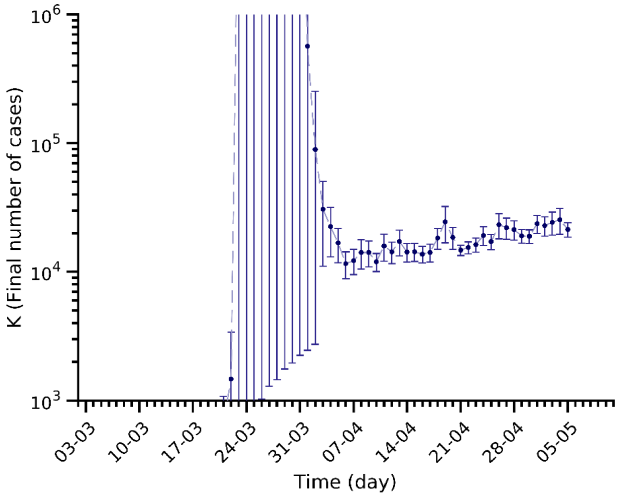


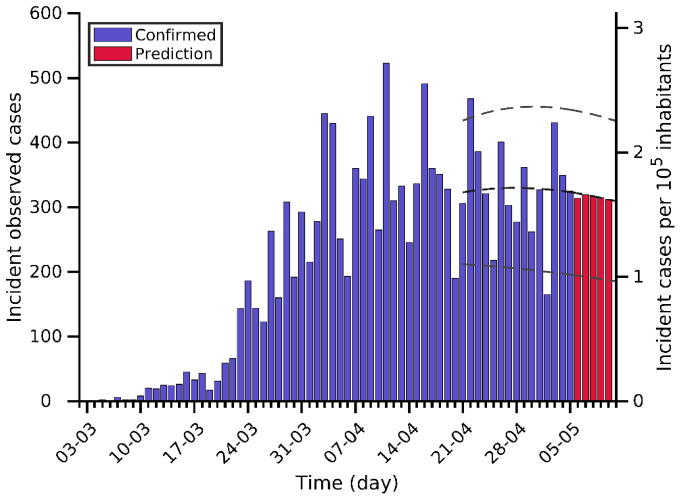
Romania 05-05-2020. Population: 19.2M. Current cumulated incidence: 72/10^5

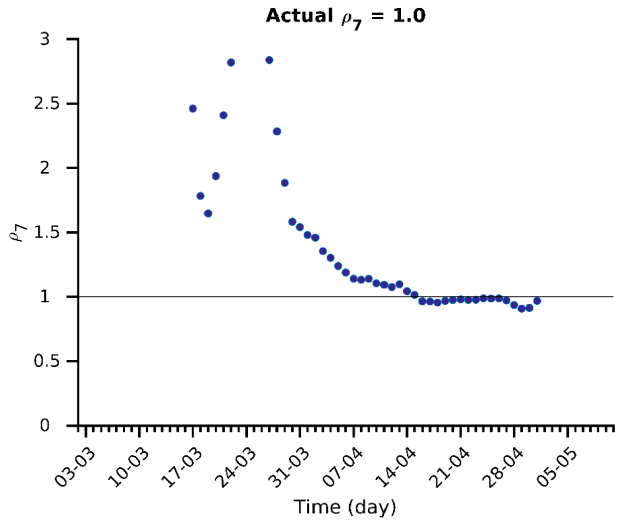


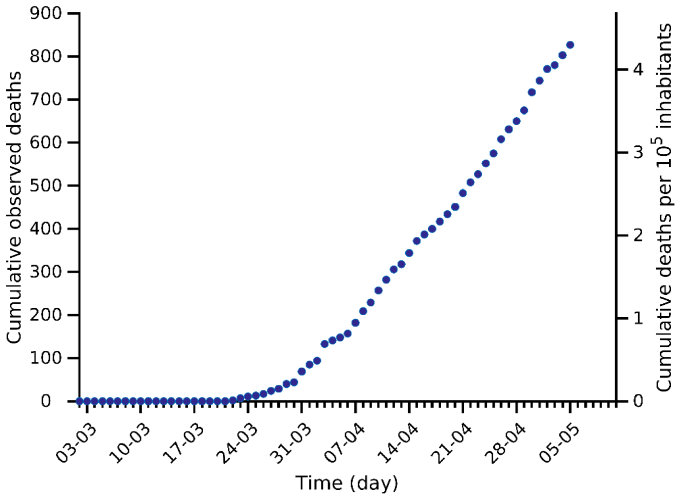


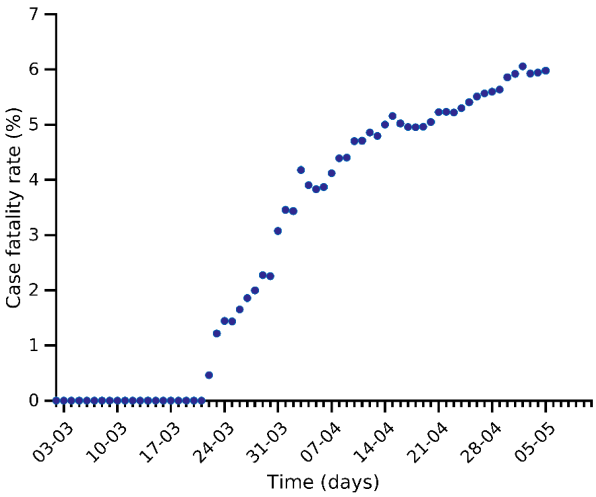




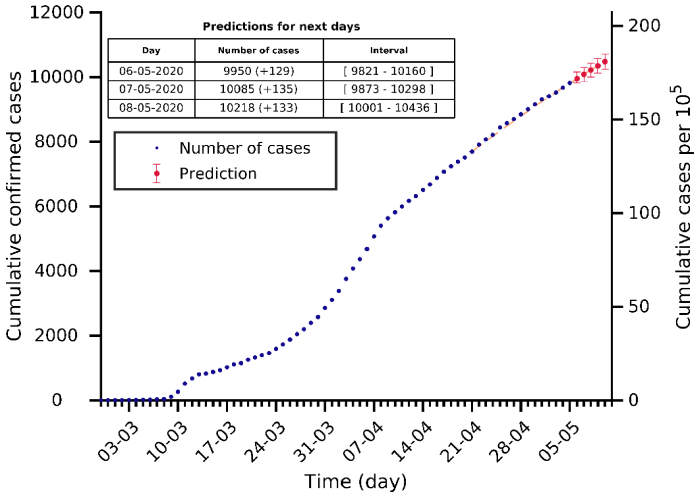


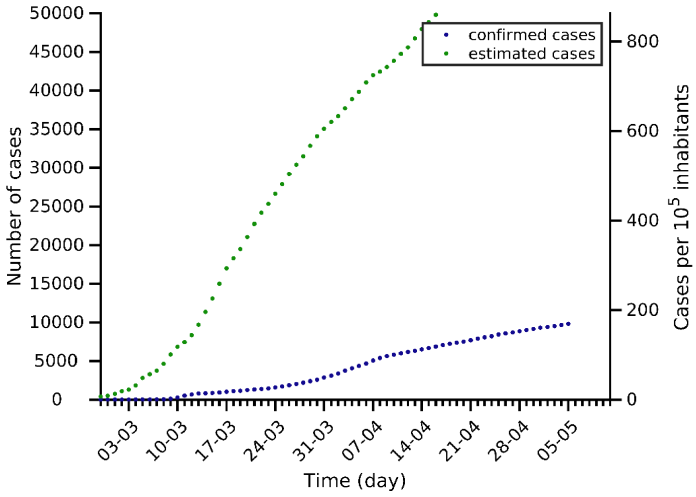


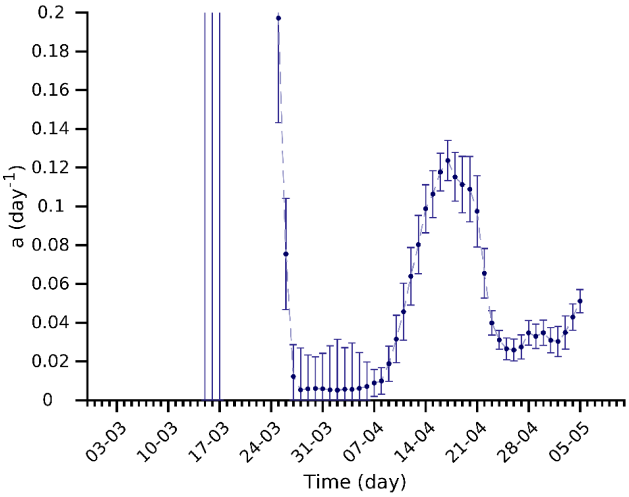


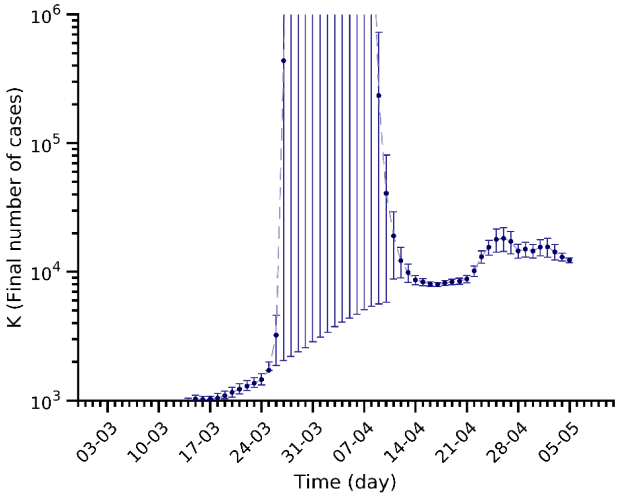


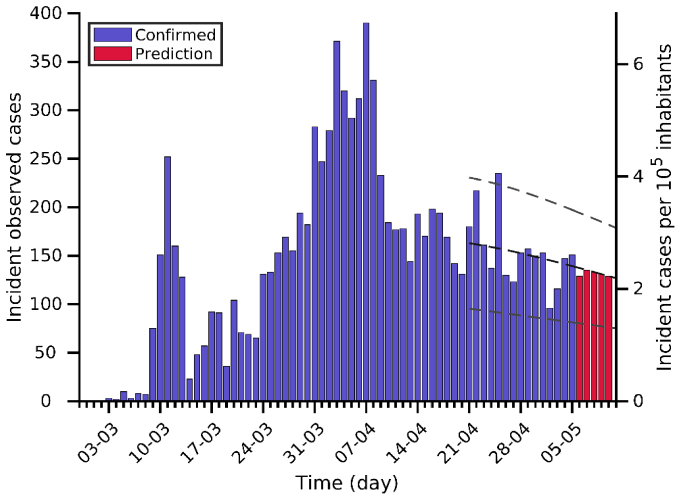
Denmark 05-05-2020. Population: 5.8M. Current cumulated incidence: $170/10^5$

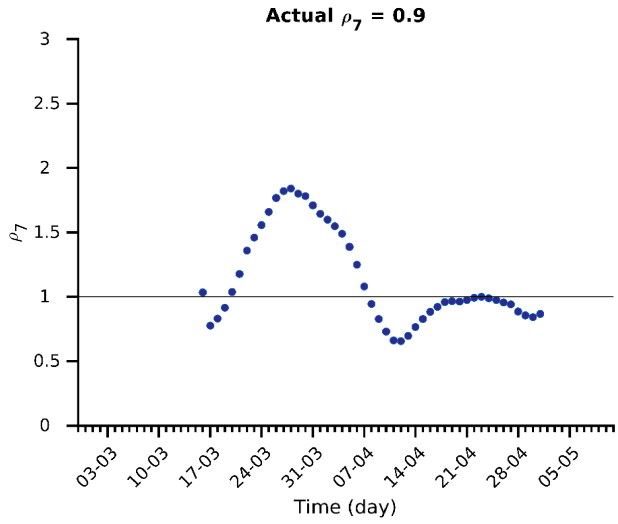


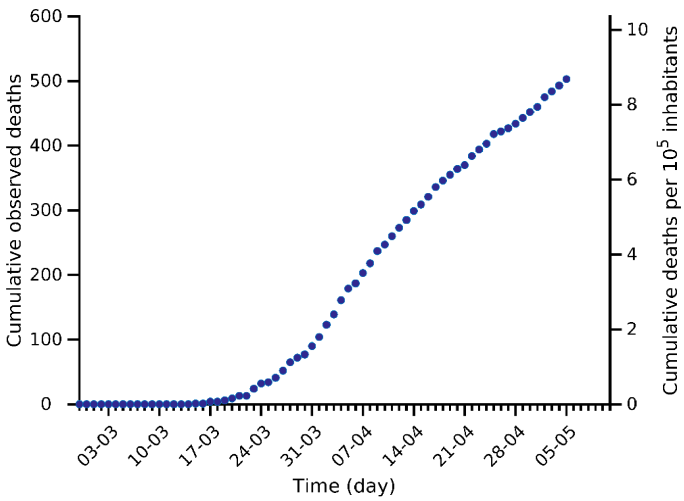


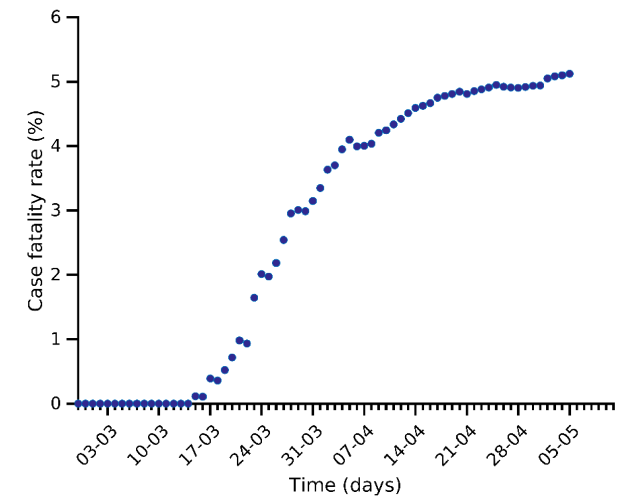




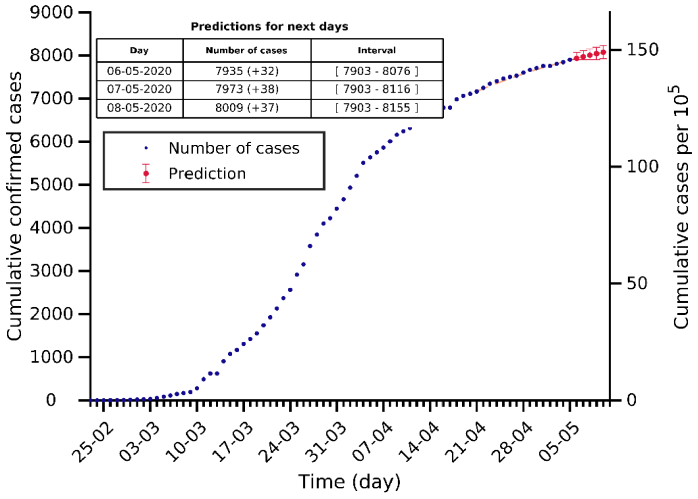


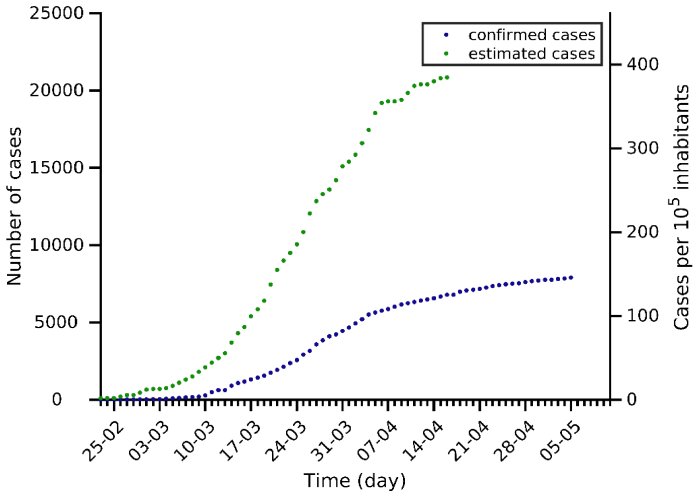


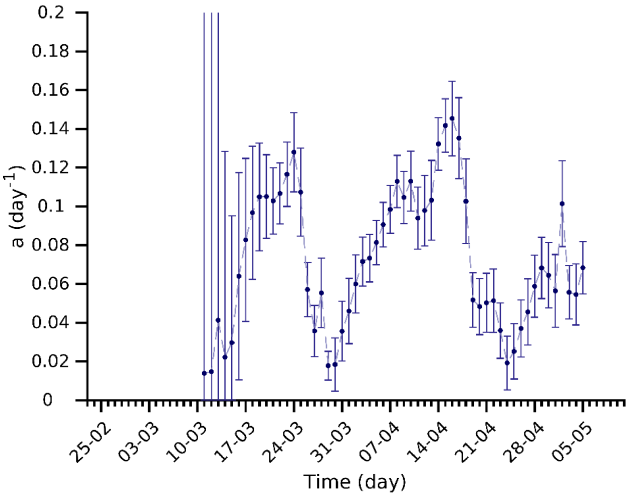


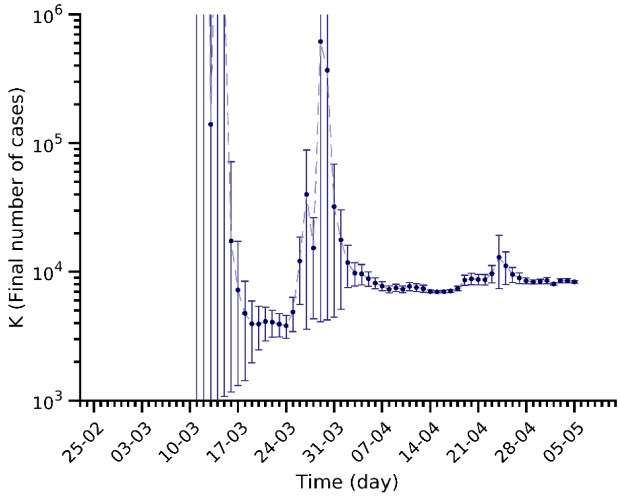


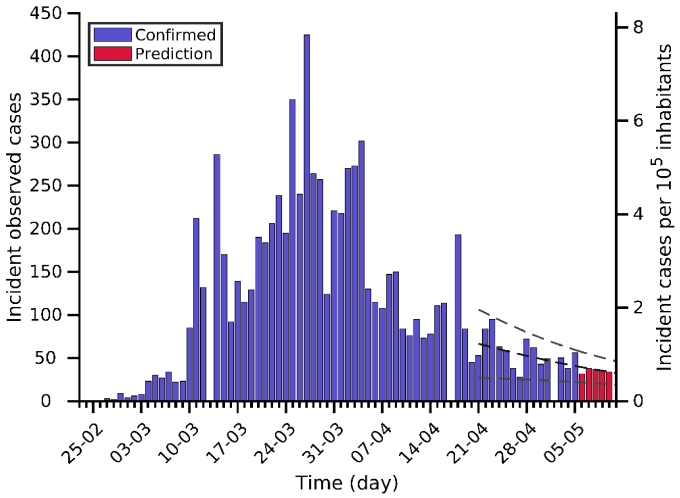
Norway 05-05-2020. Population: 5.4M. Current cumulated incidence: 146/10⁵

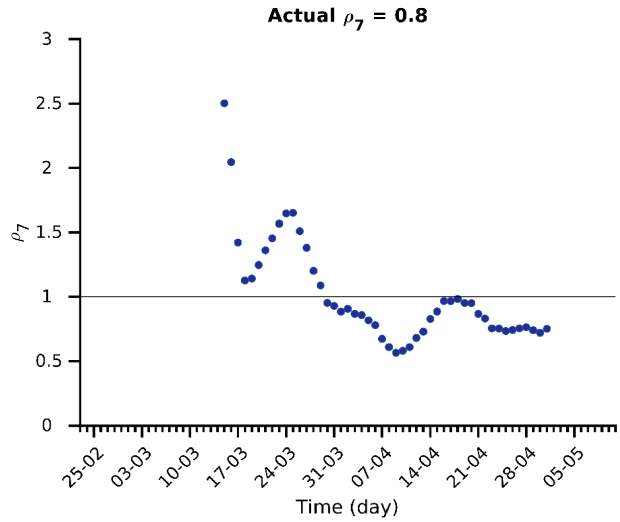


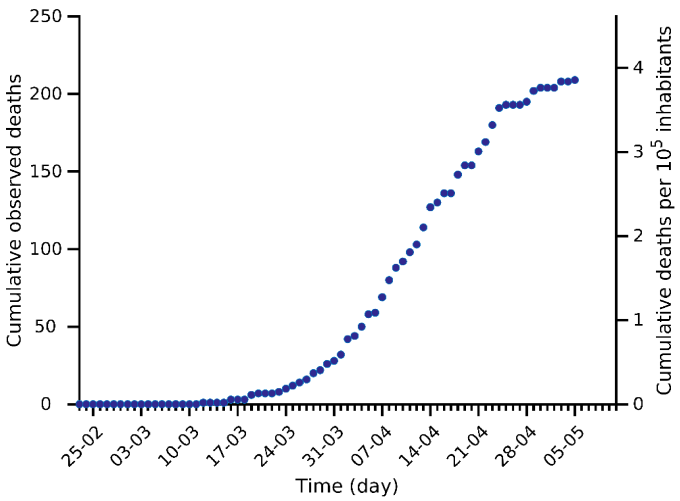


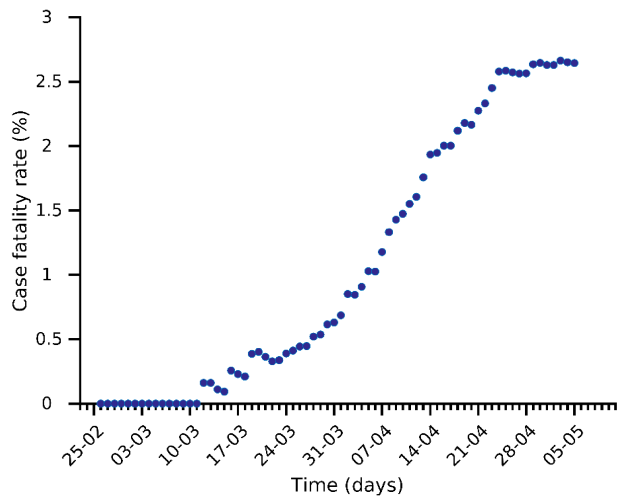




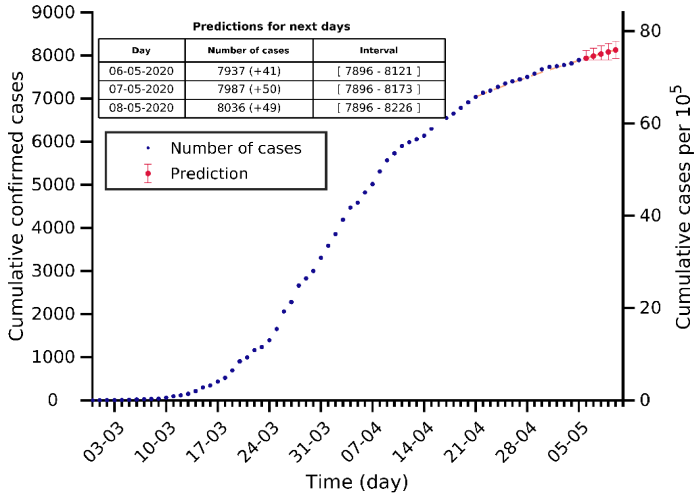


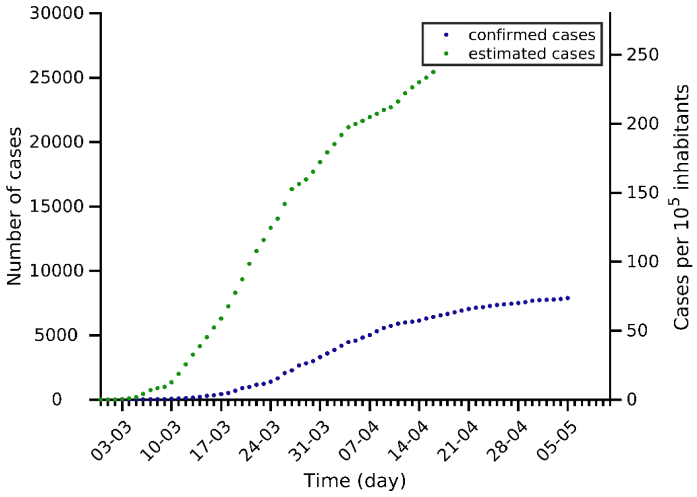


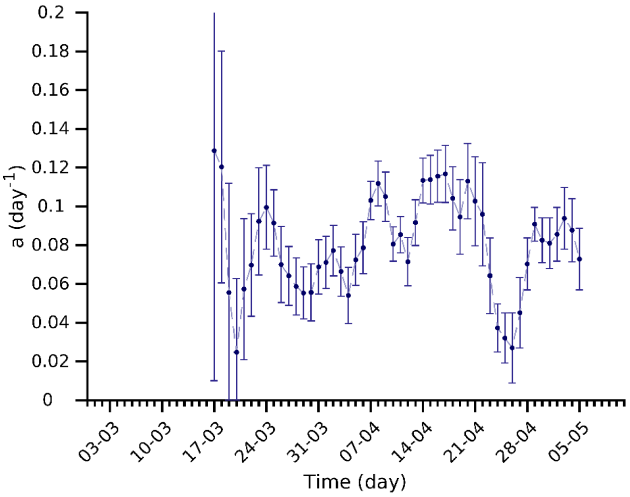


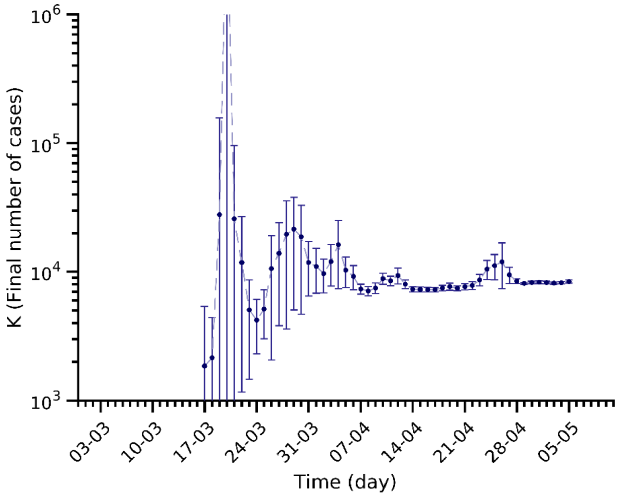


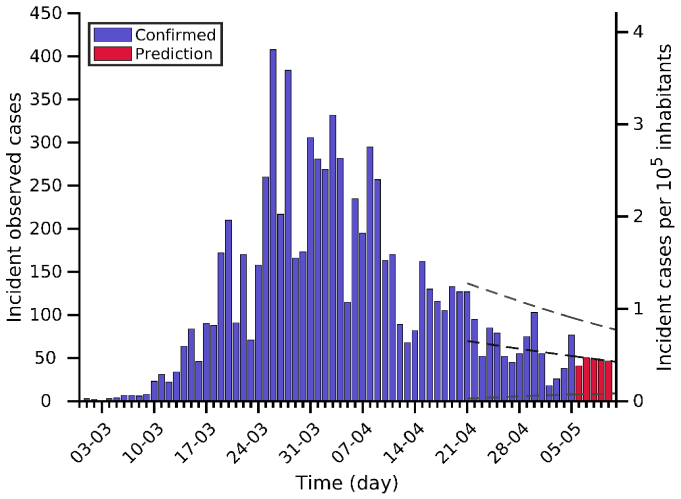
Czech Rep 05-05-2020. Population: 10.7M. Current cumulated incidence: 74/10^5

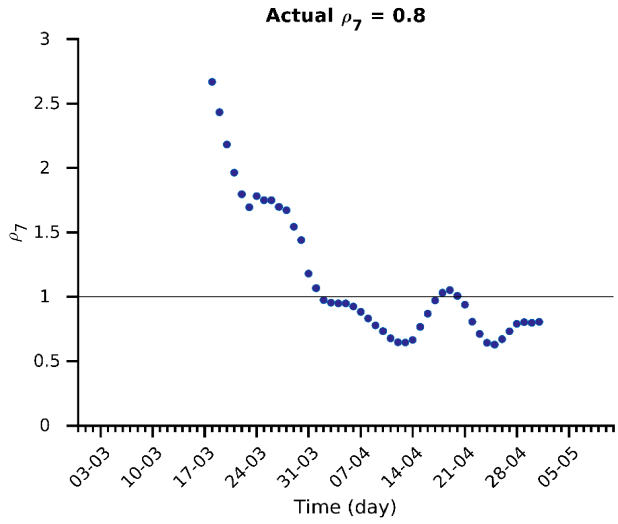


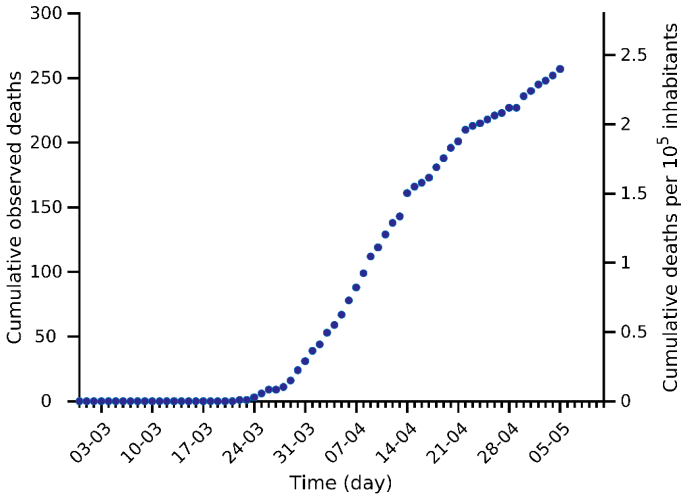


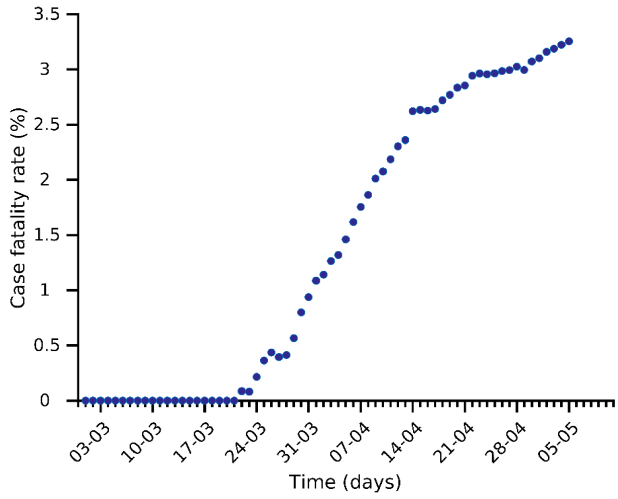




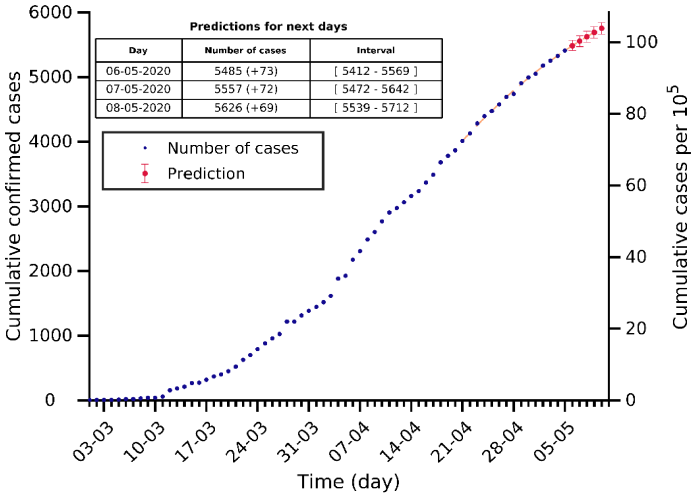


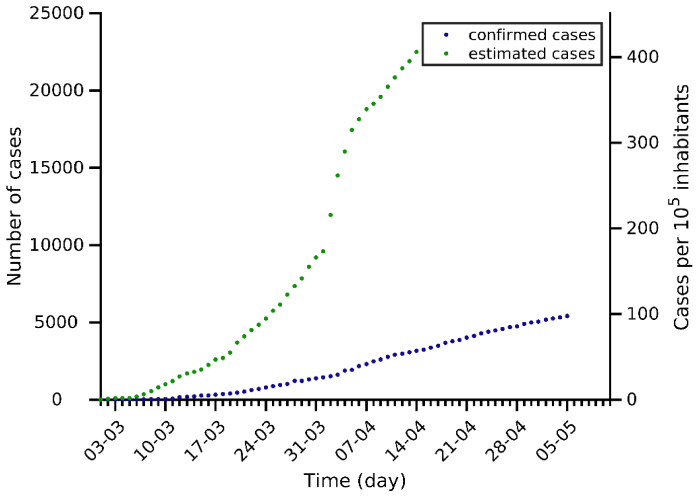


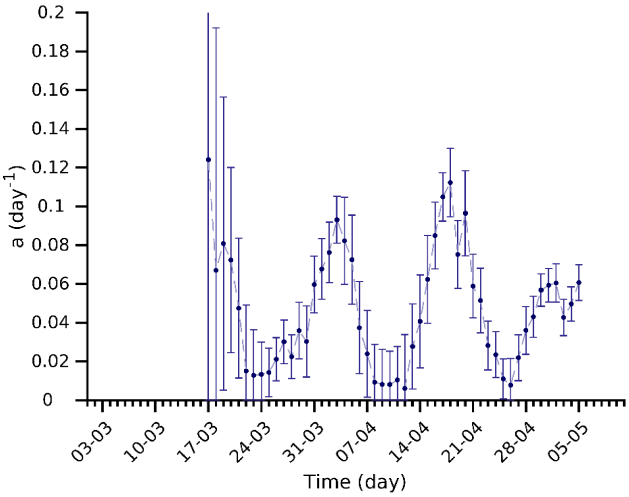


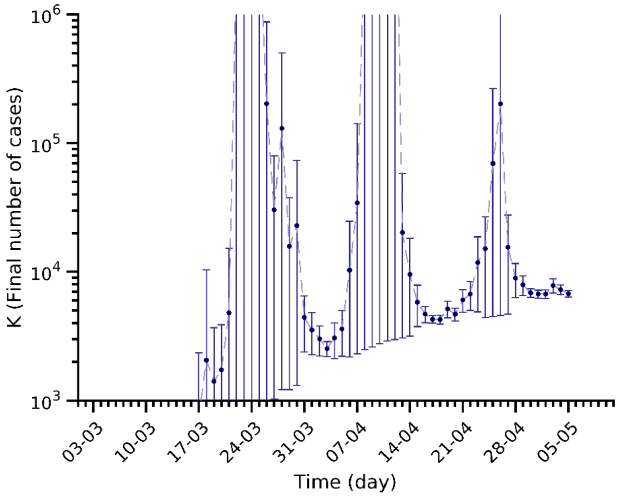


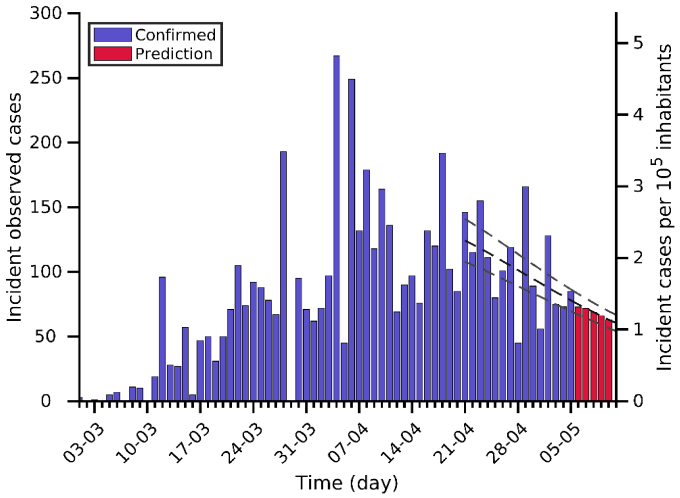
Finland 05-05-2020. Population: 5.5M. Current cumulated incidence: 98/10^5

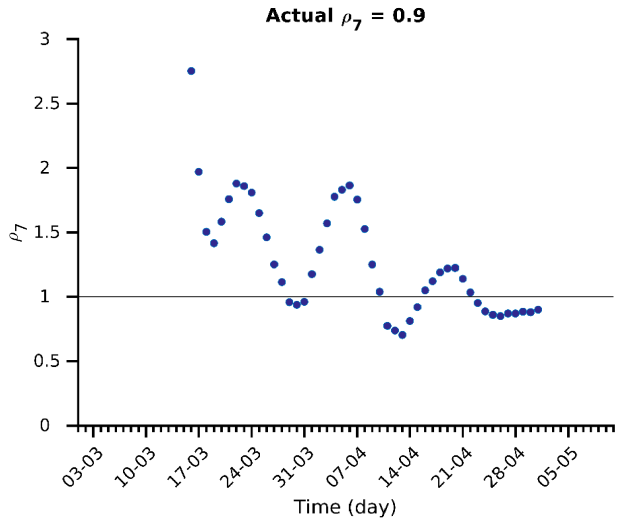


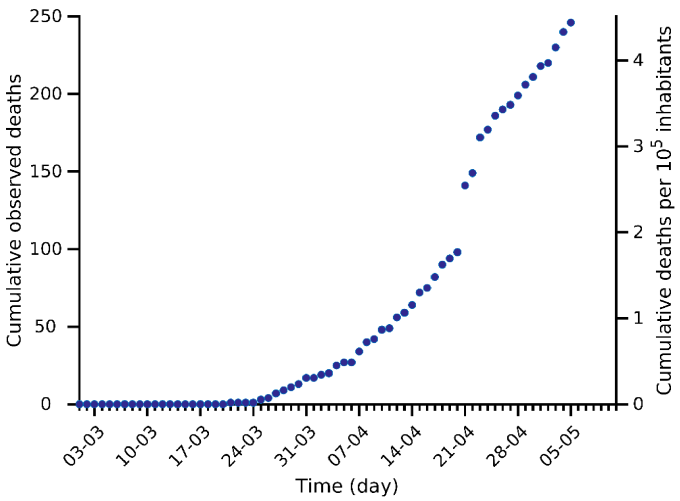


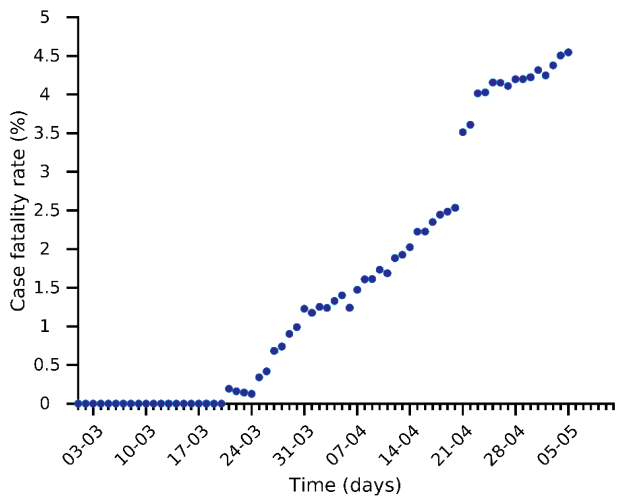




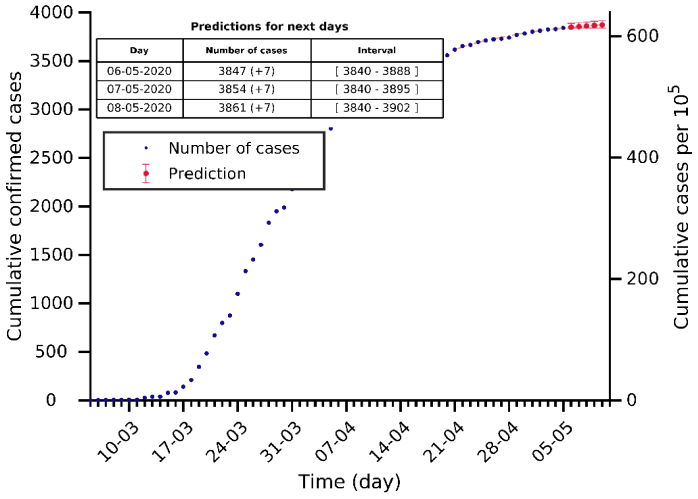


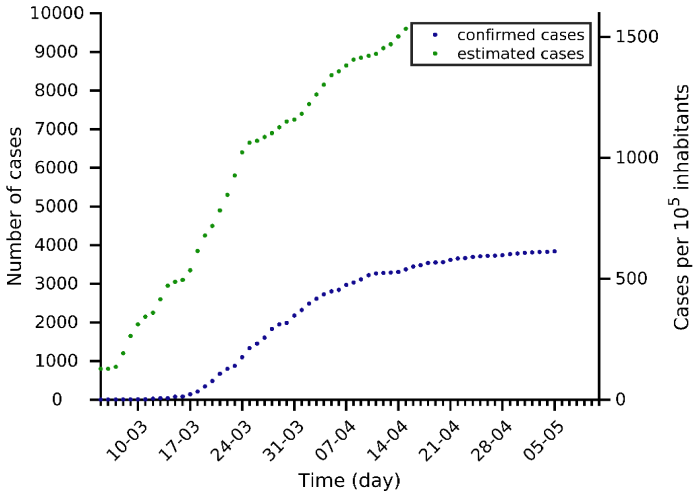


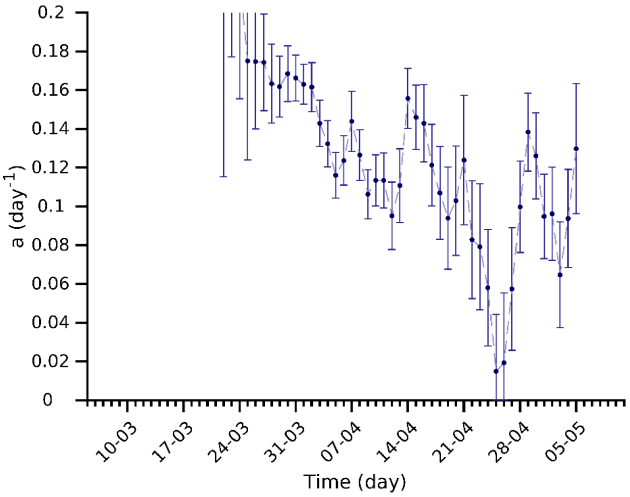


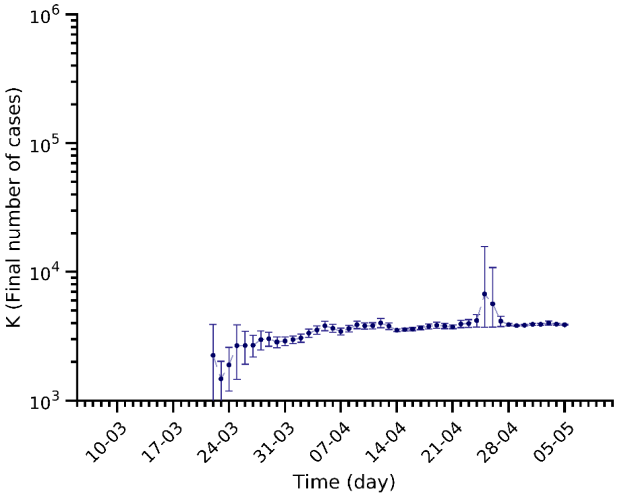


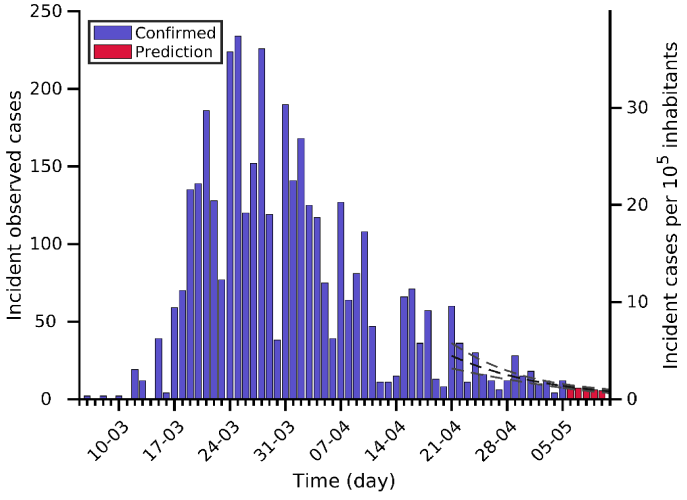
Luxembourg 05-05-2020. Population: 0.6M. Current cumulated incidence: 613/10^5

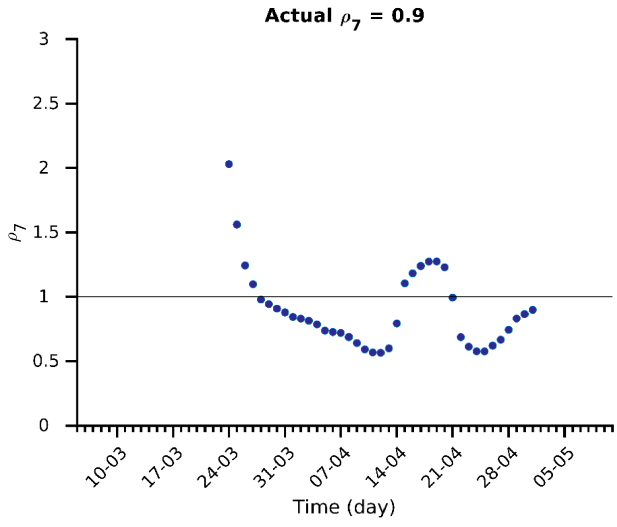


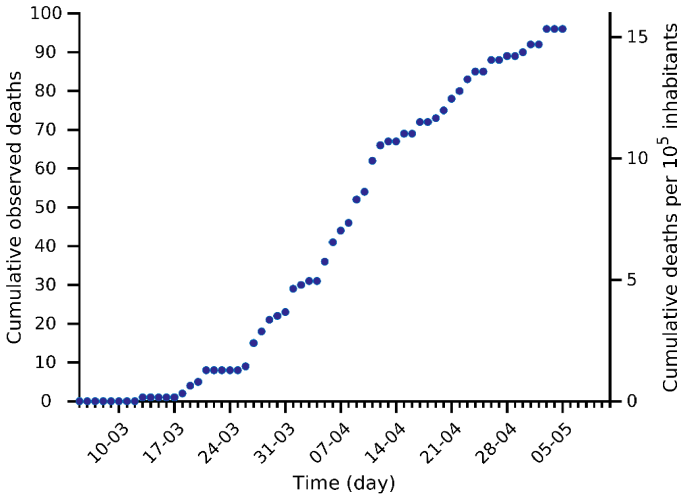


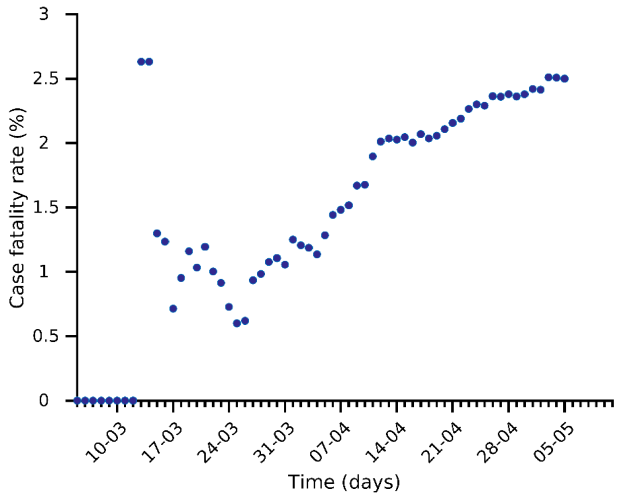








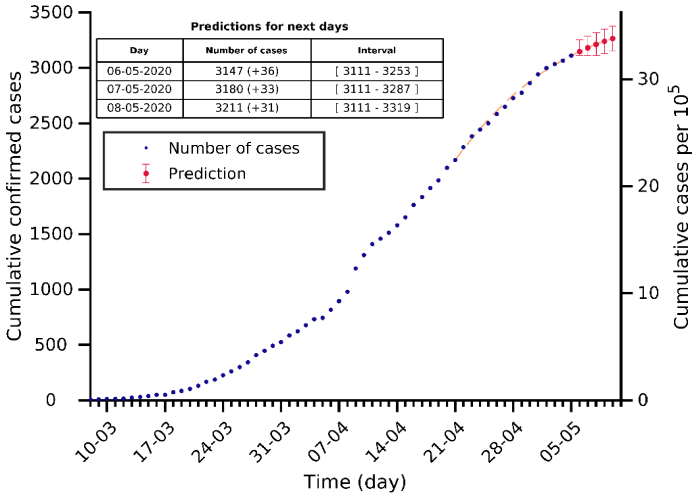


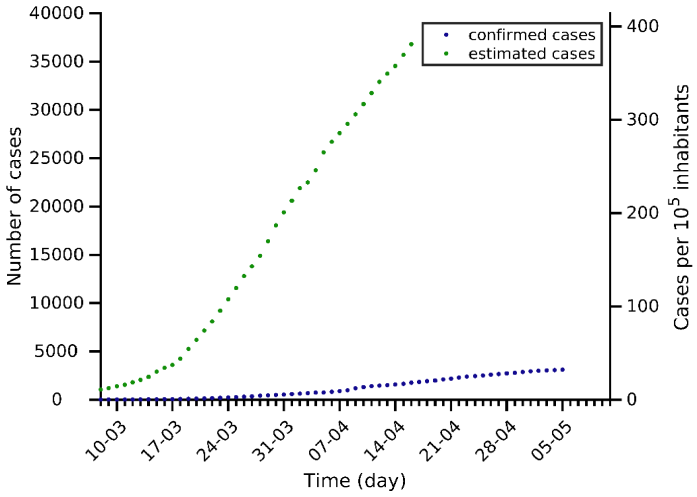


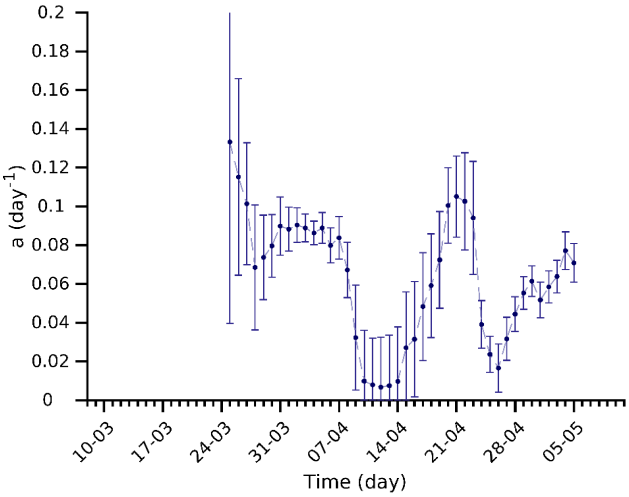
Hungary 05-05-2020. Population: 9.7M. Current cumulated incidence: $32/10^5$

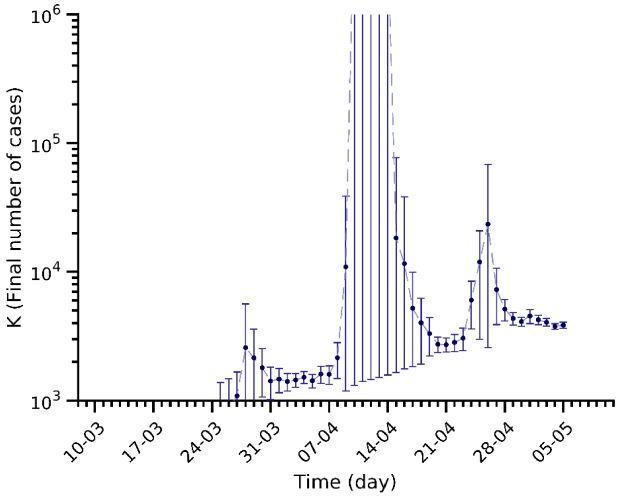
Predictions for next days

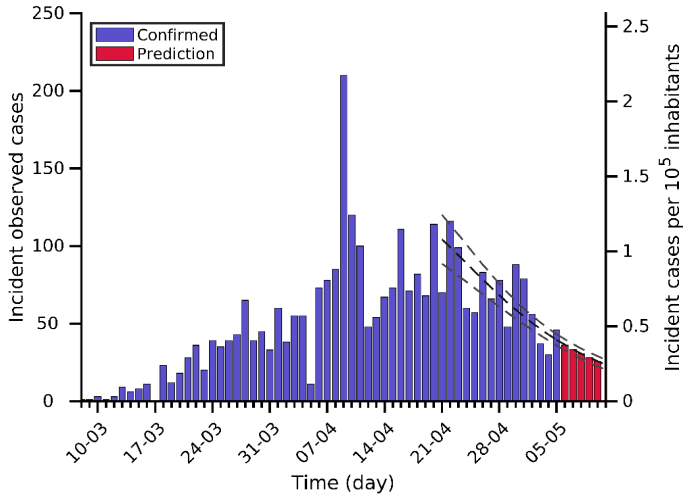
Day	Number of cases	Interval
06-05-2020	3147 (+36)	[3111 - 3253]
07-05-2020	3180 (+33)	[3111 - 3287]
08-05-2020	3211 (+31)	[3111 - 3319]

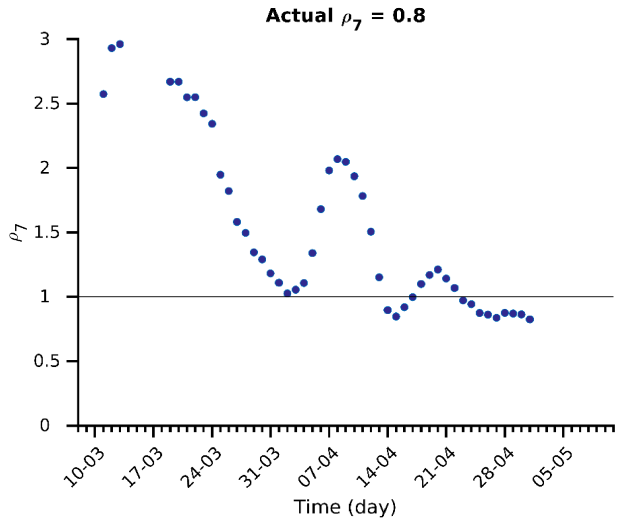


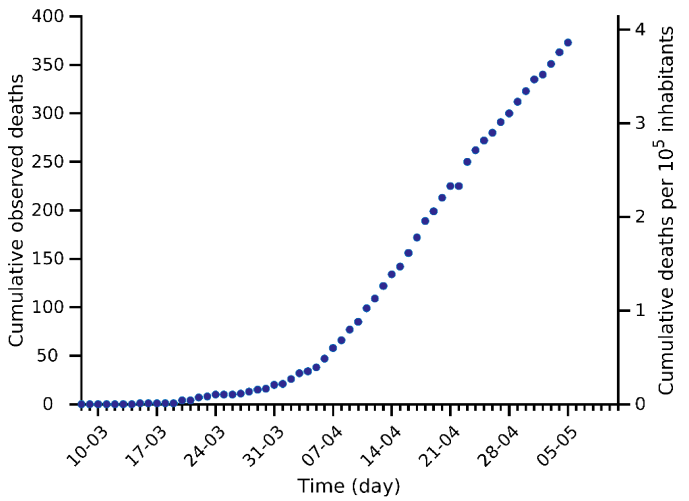


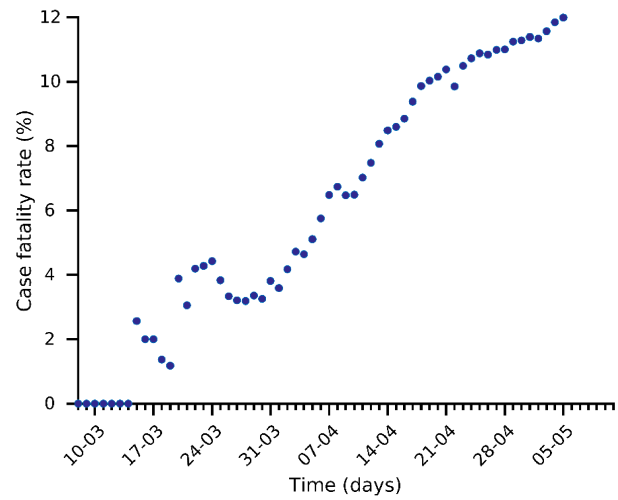




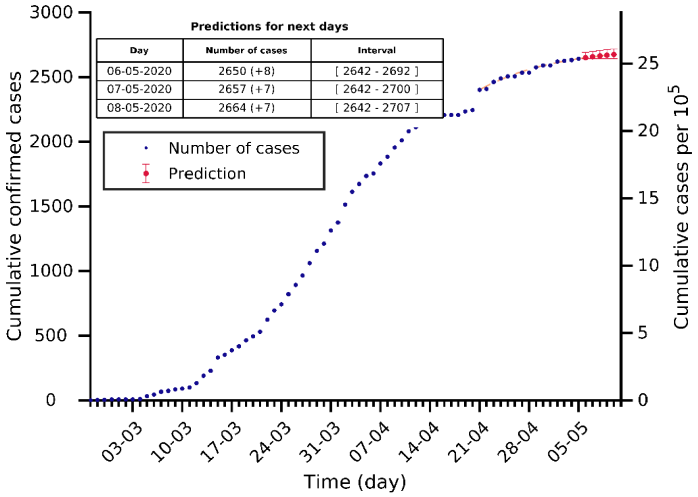


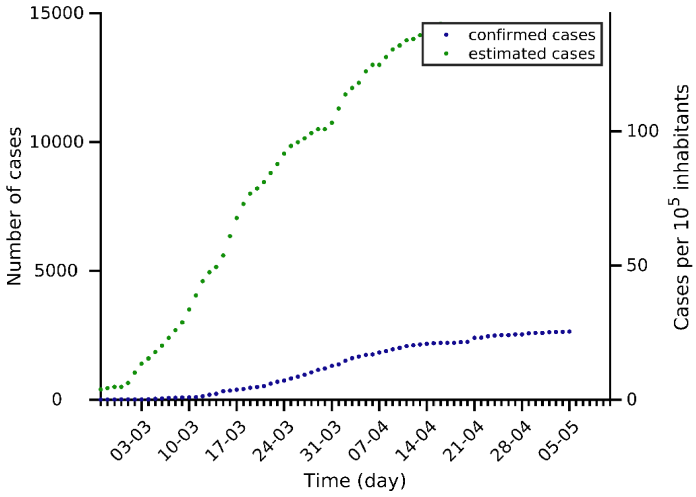


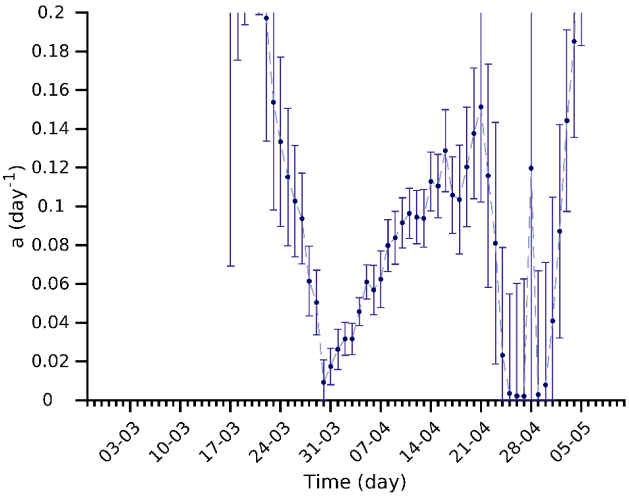


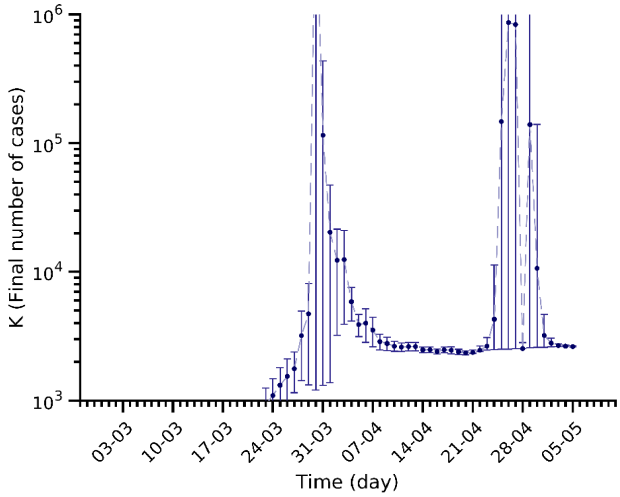


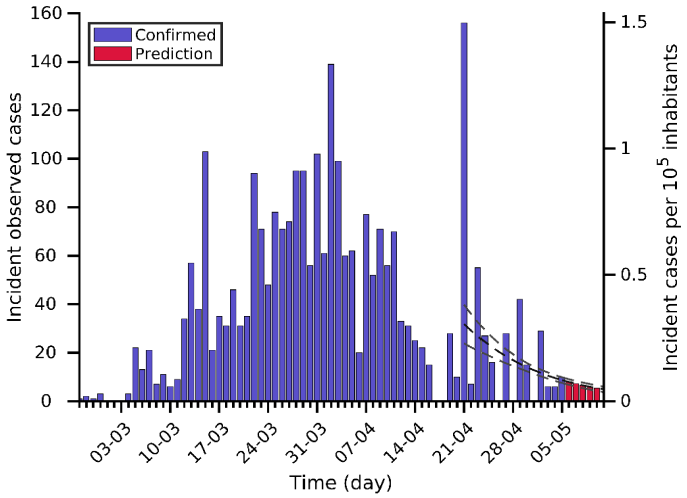
Greece 05-05-2020. Population: 10.4M. Current cumulated incidence: $25/10^5$

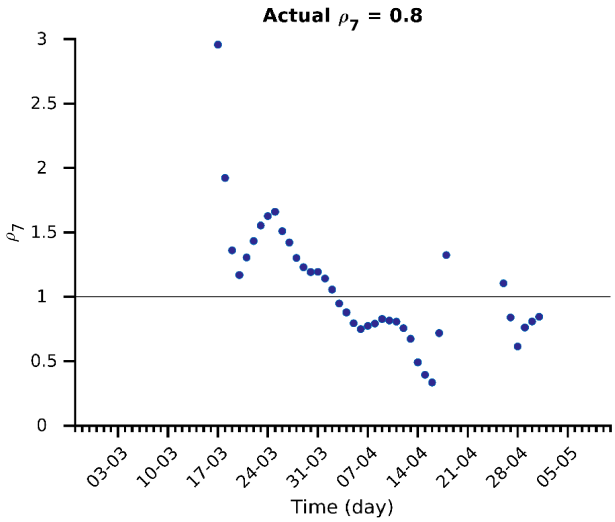


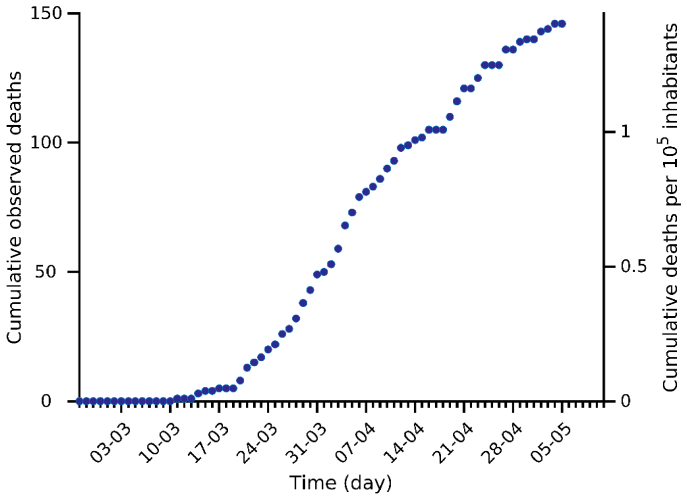


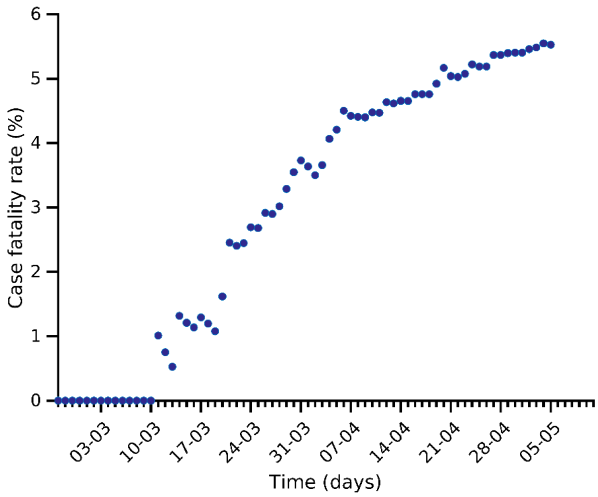




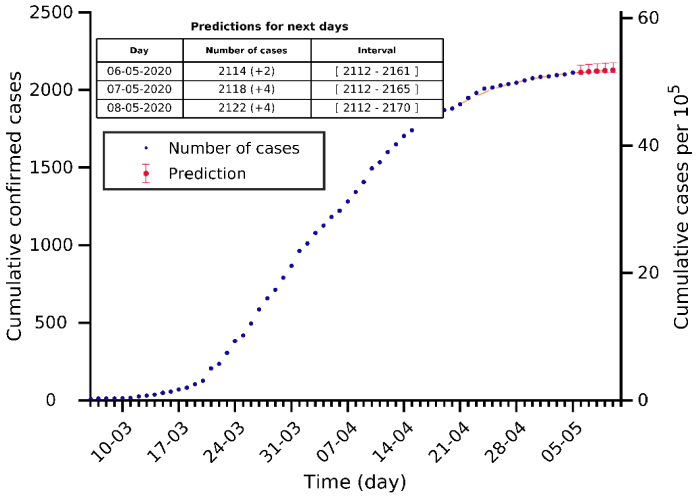


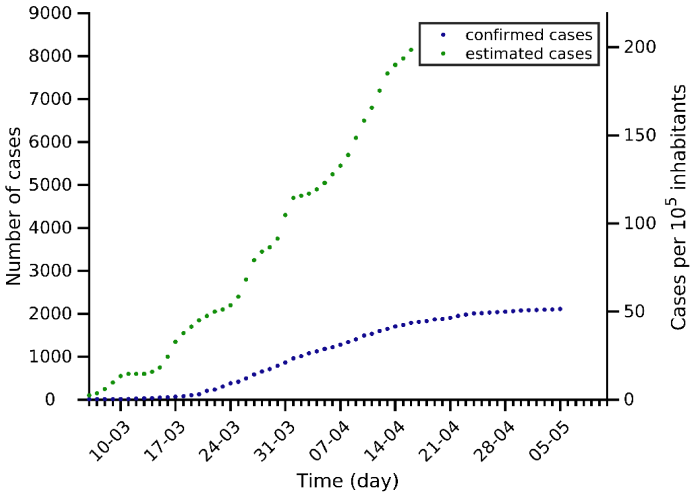


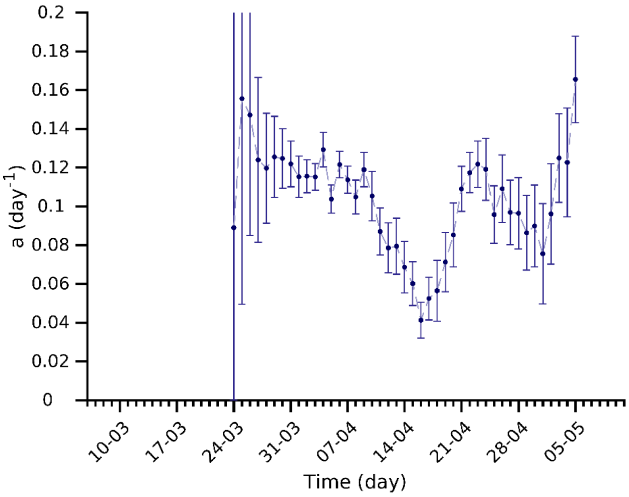


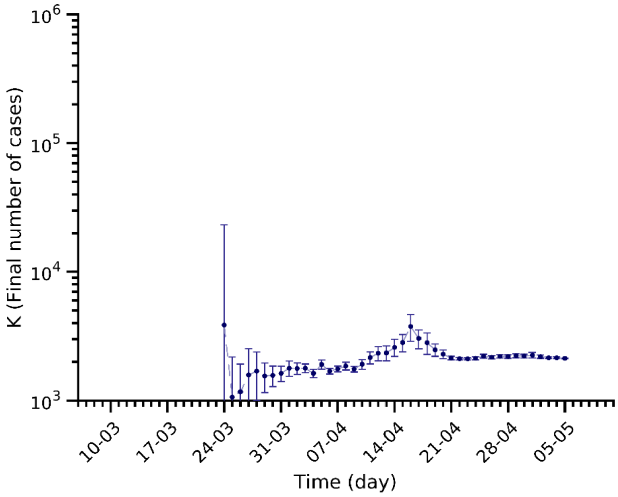


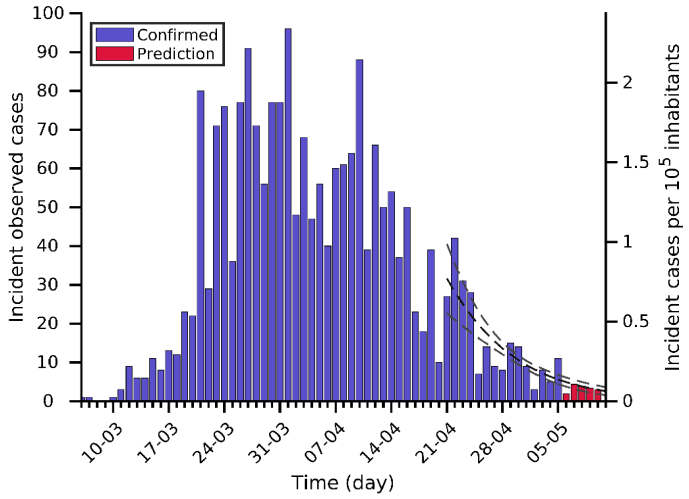
Croatia 05-05-2020. Population: 4.1M. Current cumulated incidence: $51/10^5$

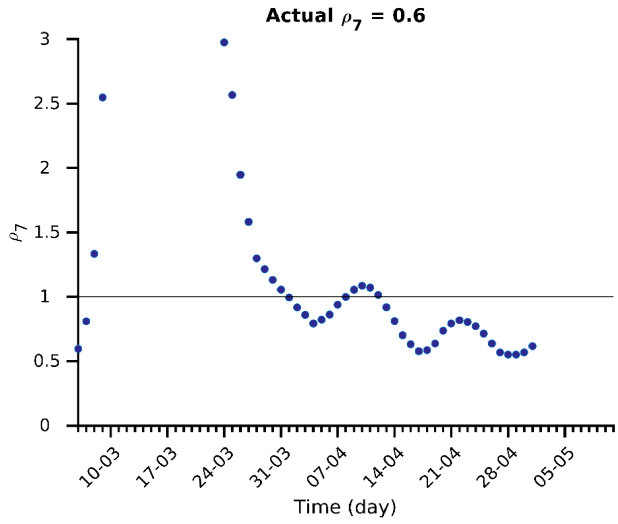


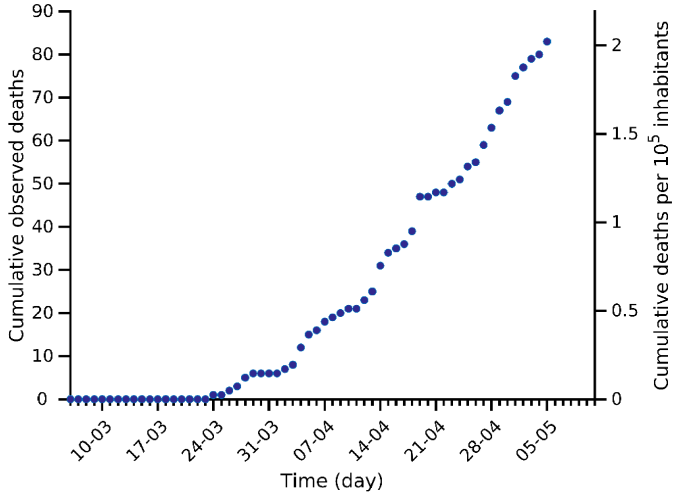


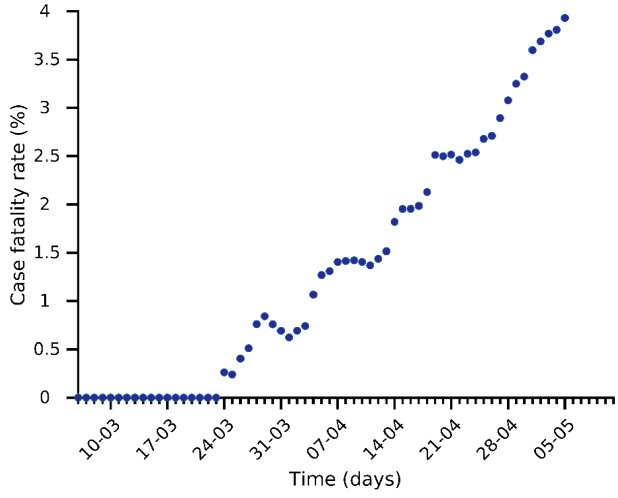




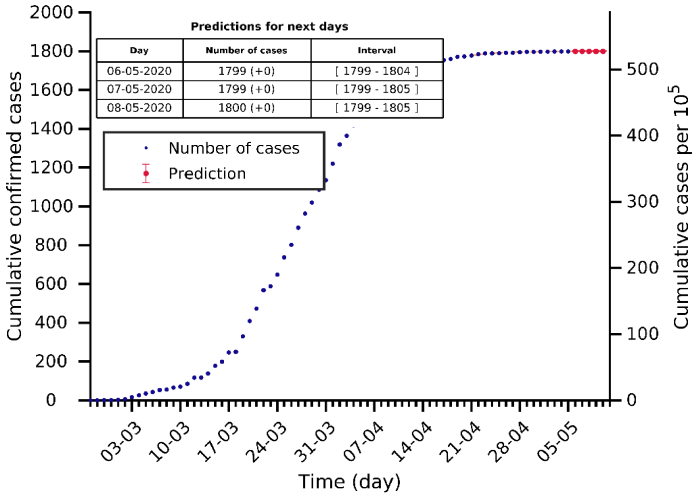


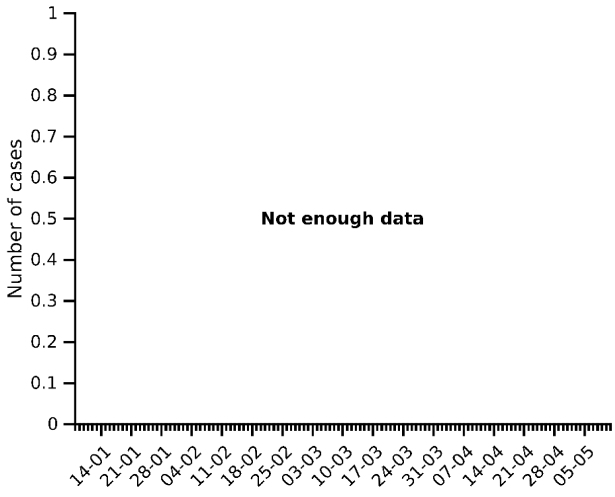


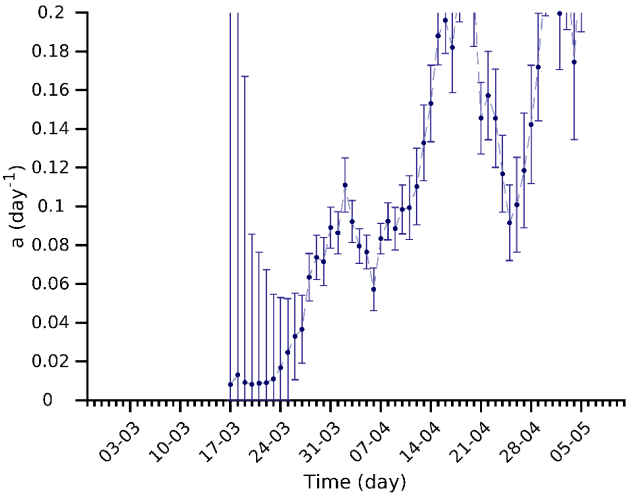


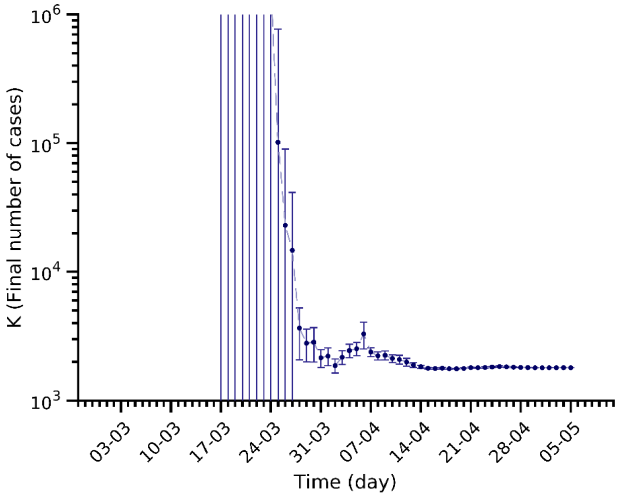


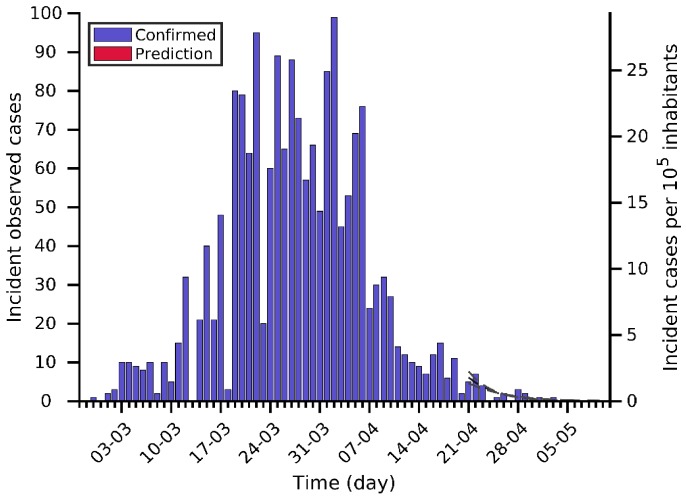
Iceland 05-05-2020. Population: 0.3M. Current cumulated incidence: 527/10^5

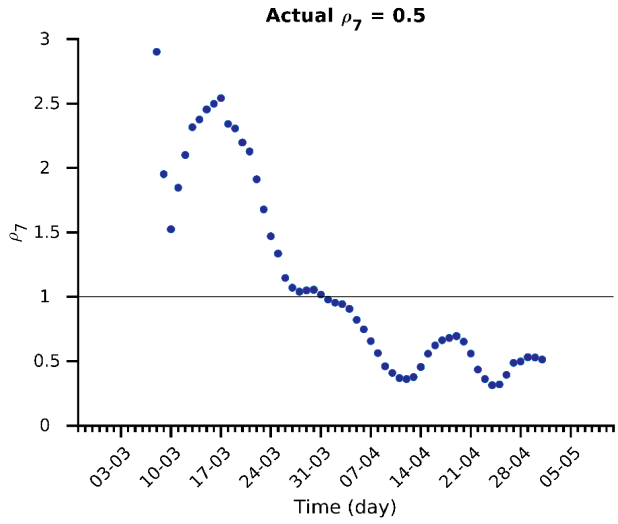


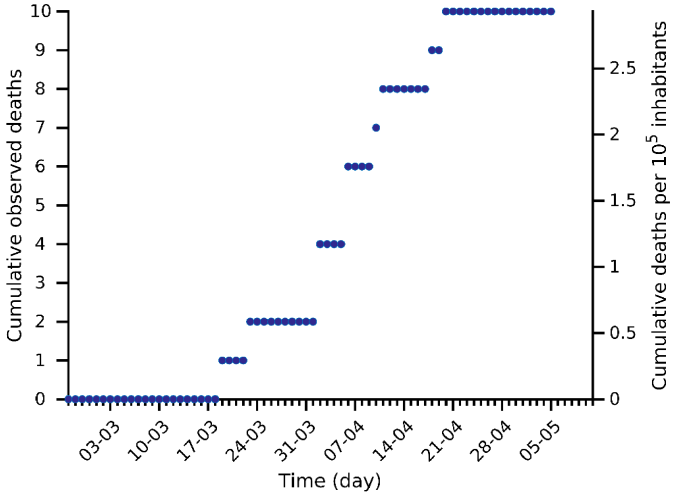


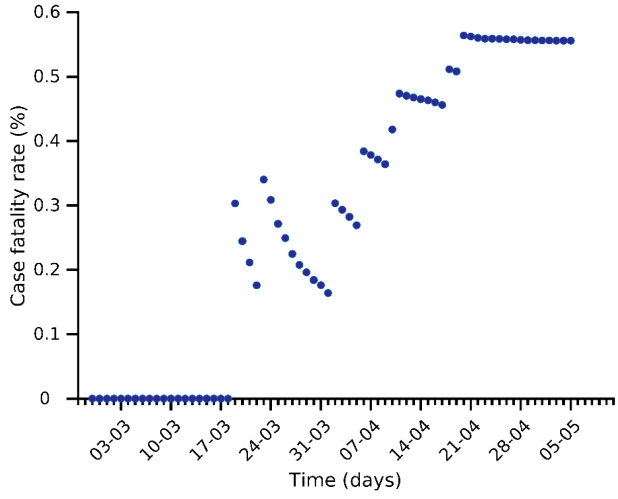




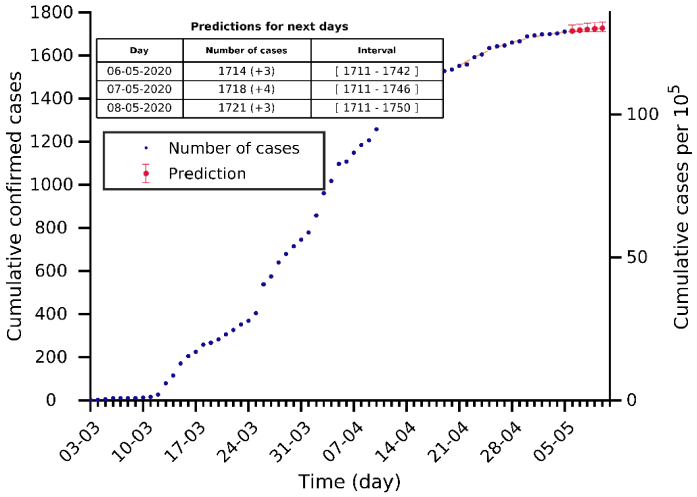


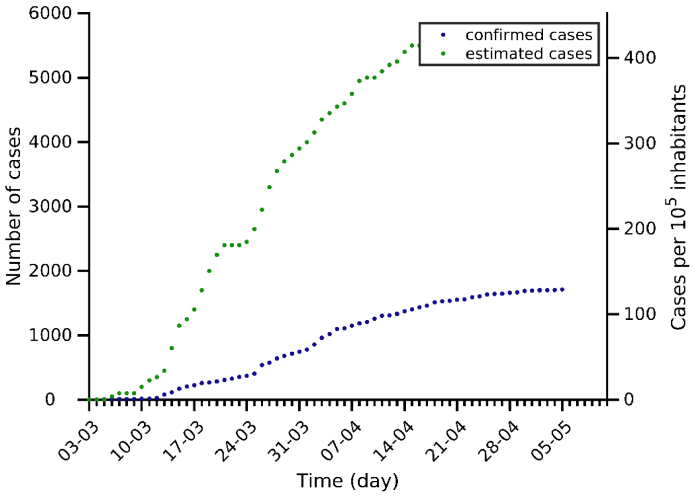


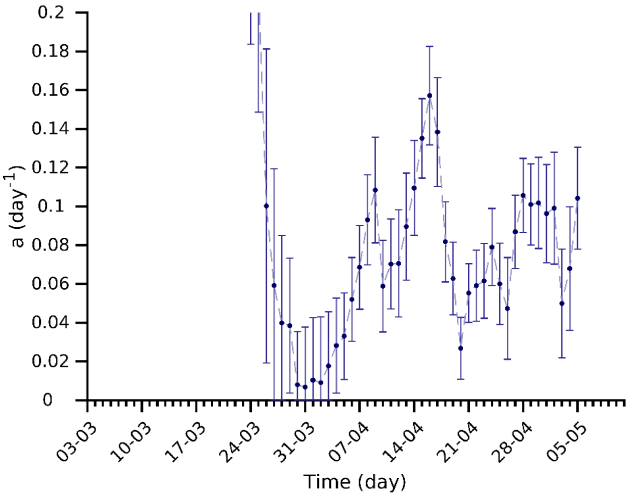


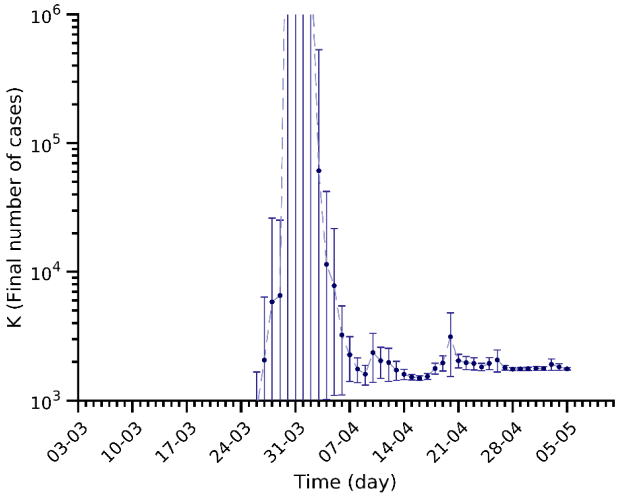


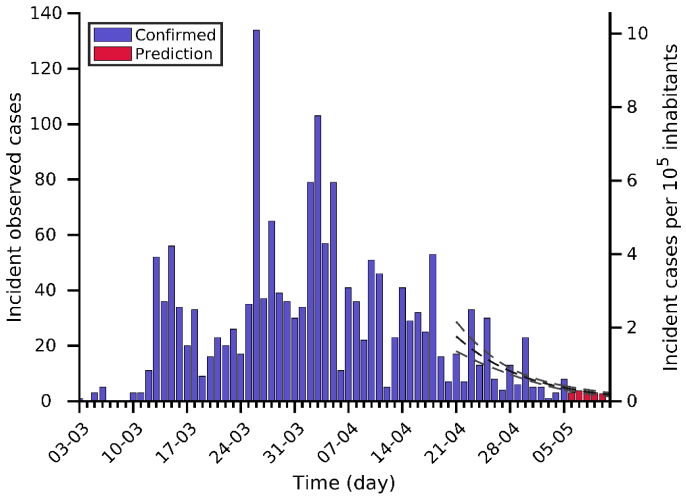
Estonia 05-05-2020. Population: 1.3M. Current cumulated incidence: $129/10^5$

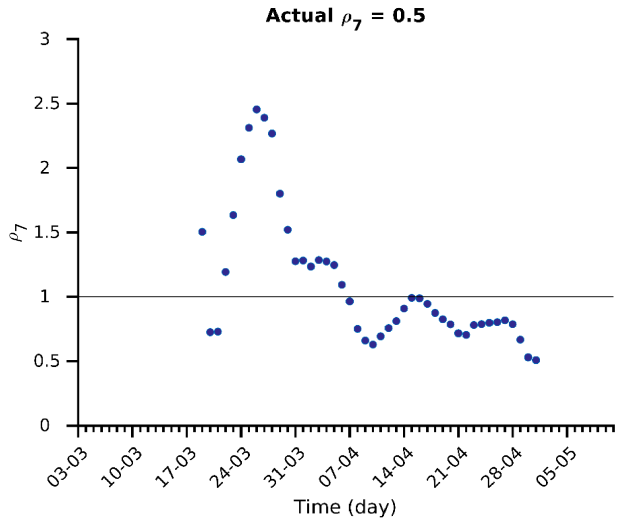


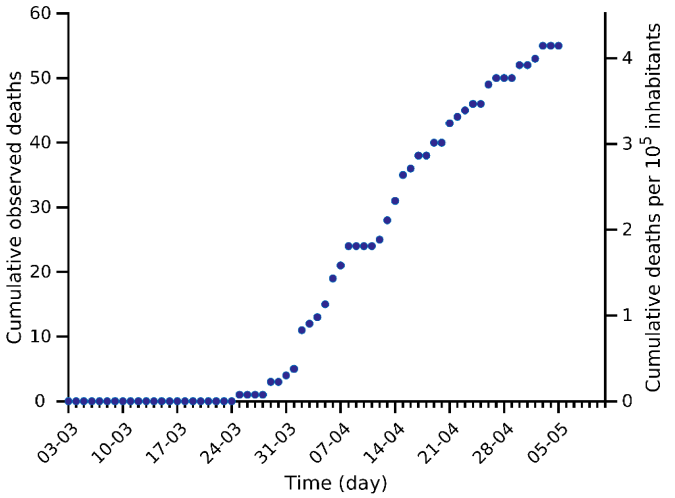


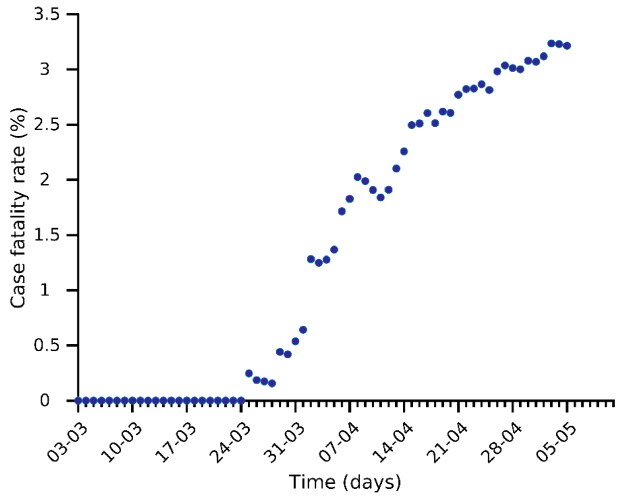




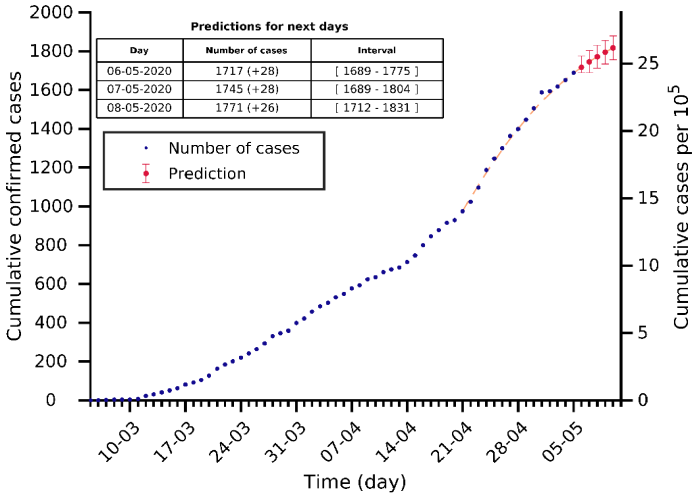


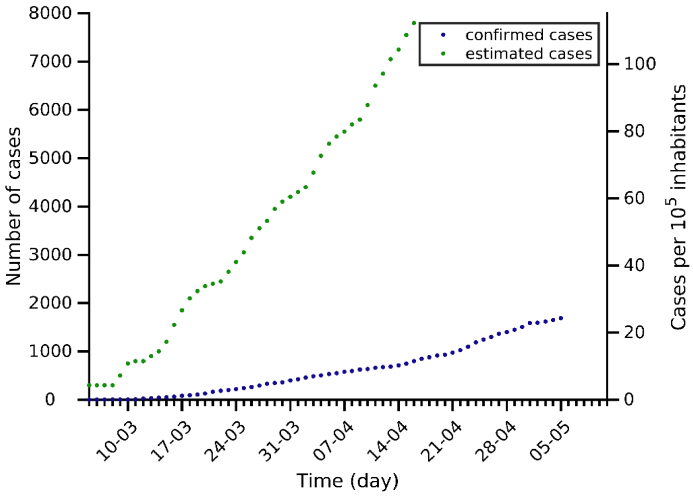


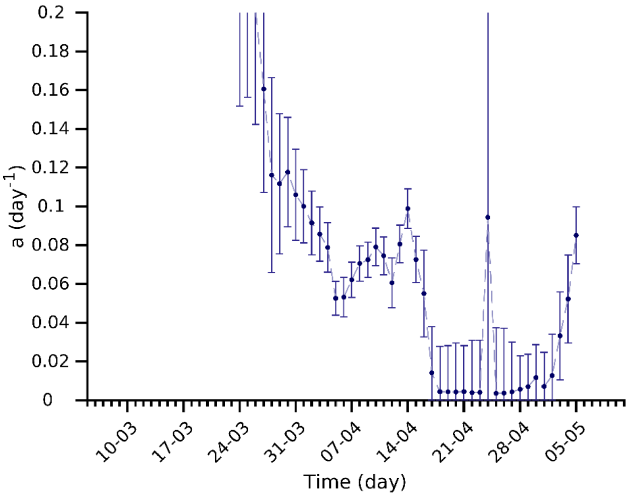


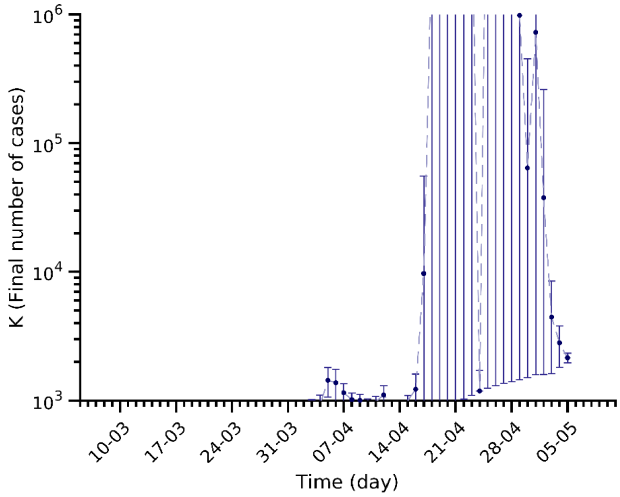


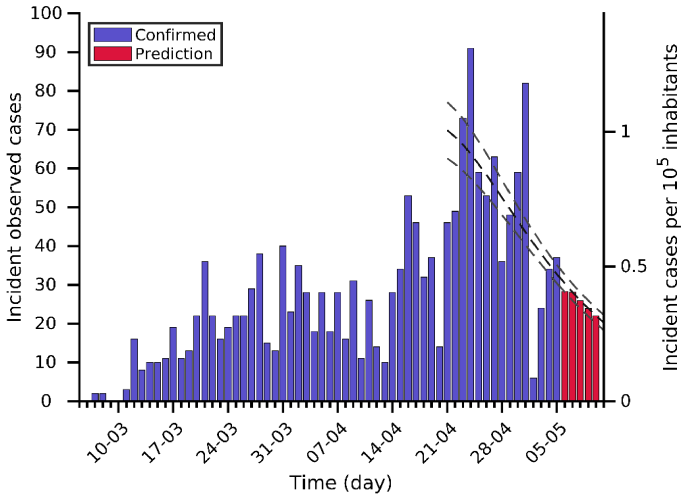
Bulgaria 05-05-2020. Population: 6.9M. Current cumulated incidence: 24/10^5

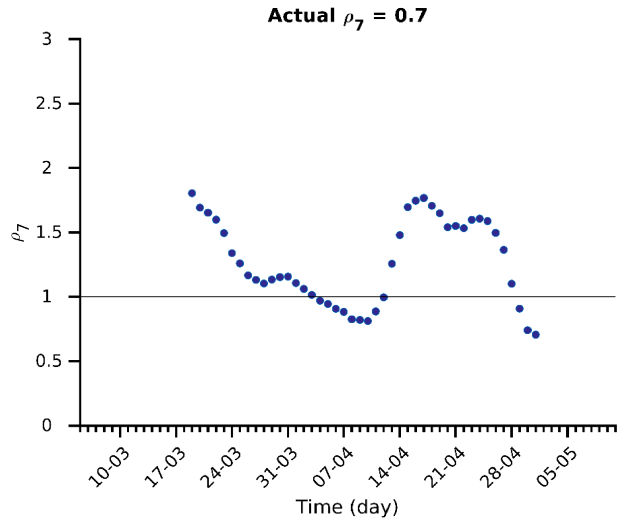


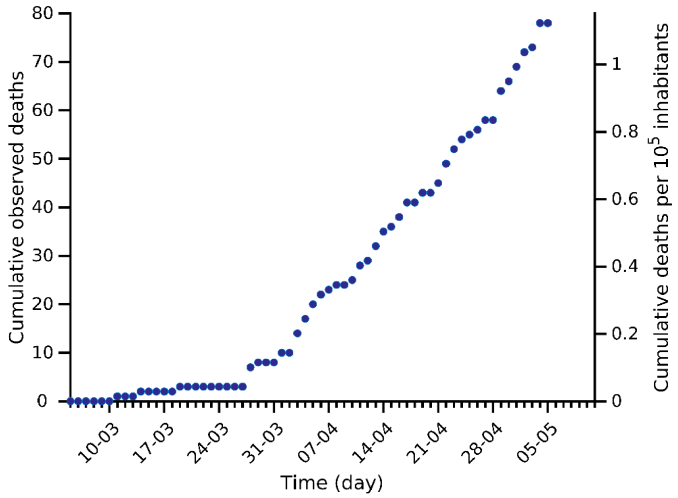


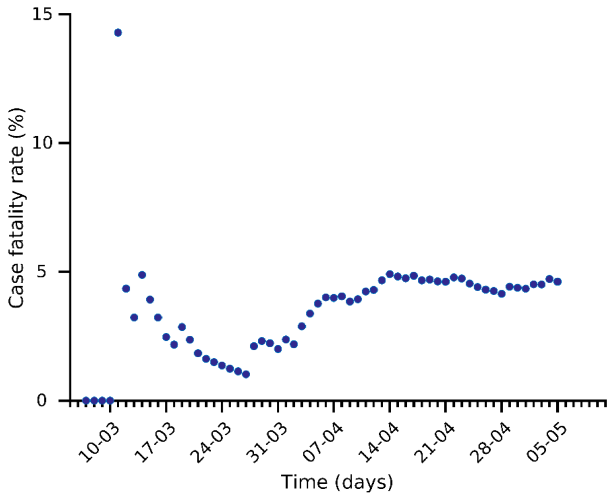




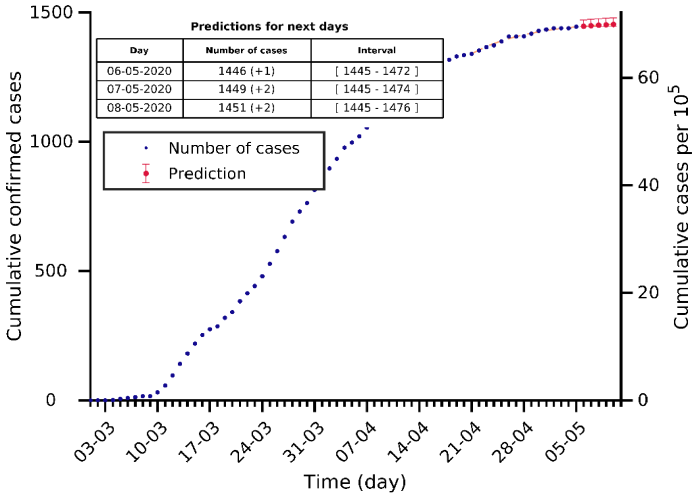


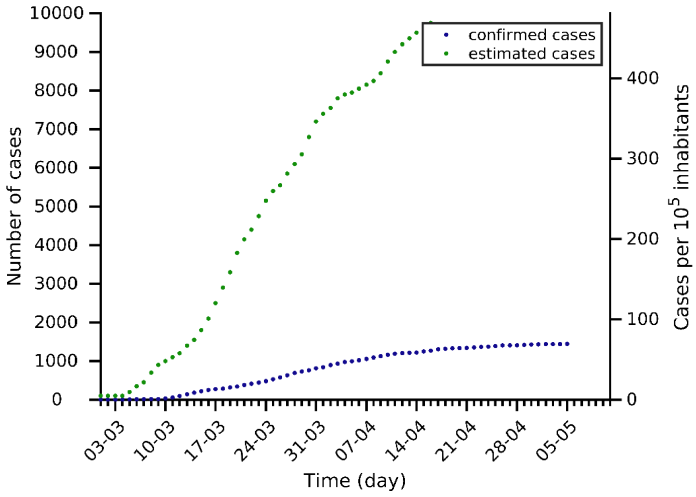


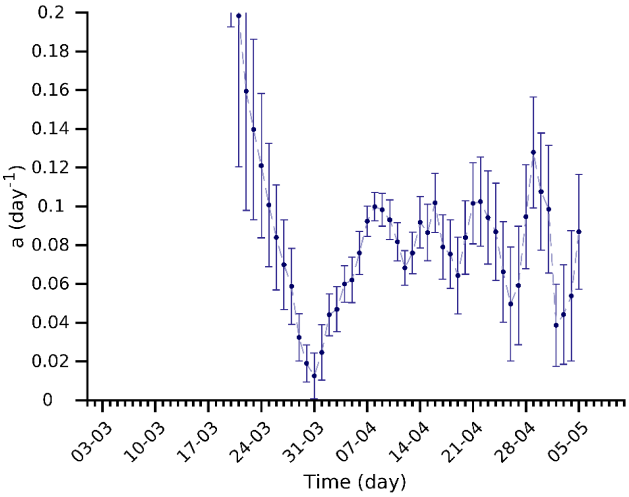


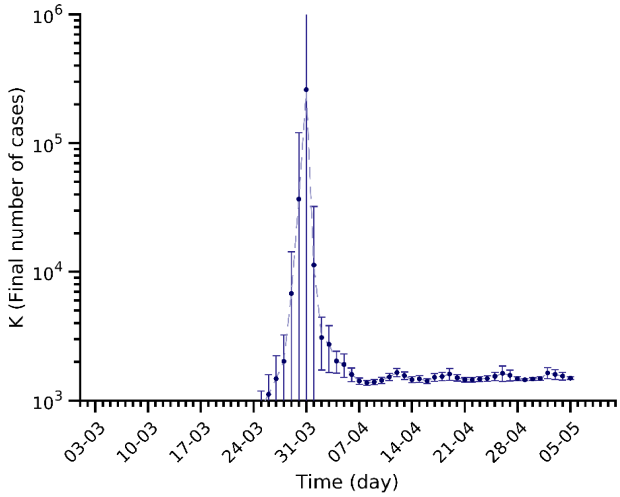


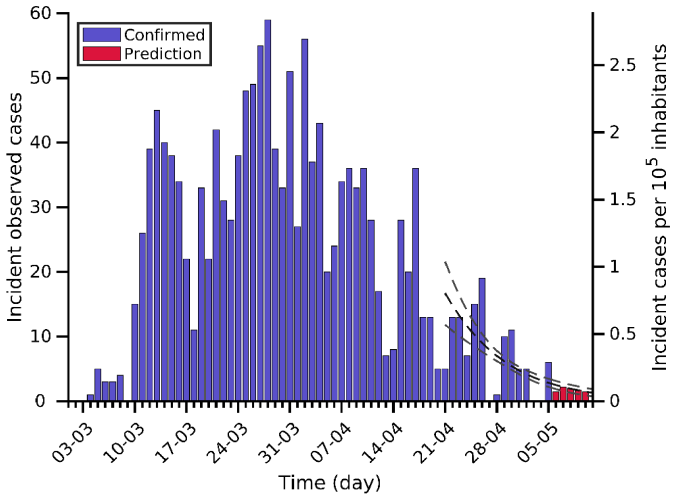
Slovenia 05-05-2020. Population: 2.1M. Current cumulated incidence: 70/10^5

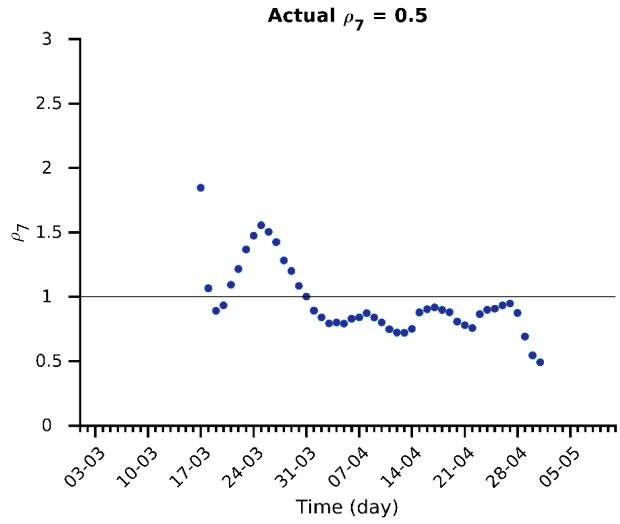


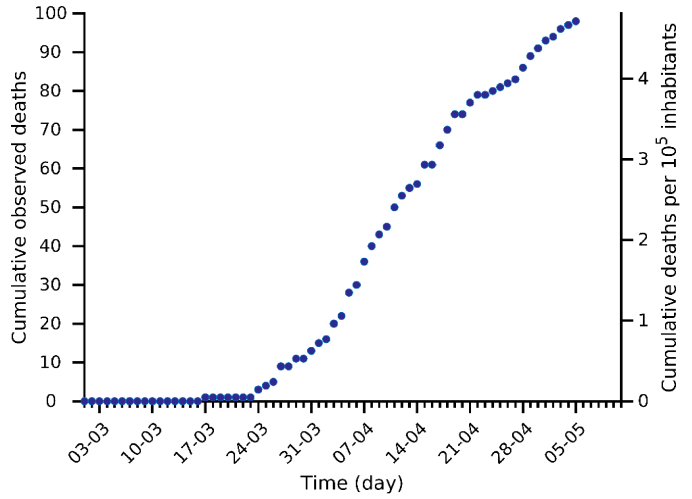


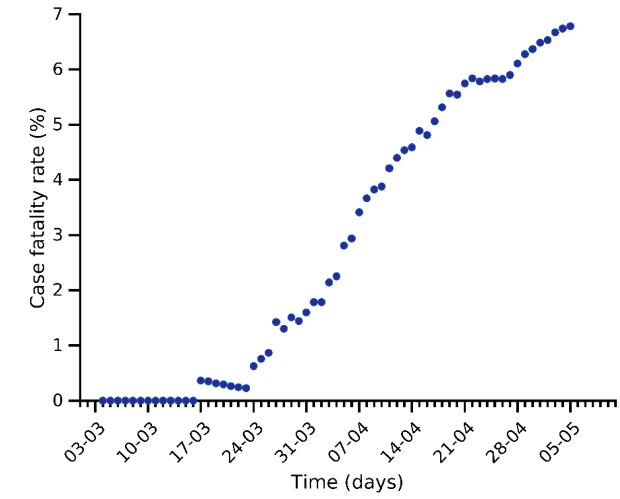




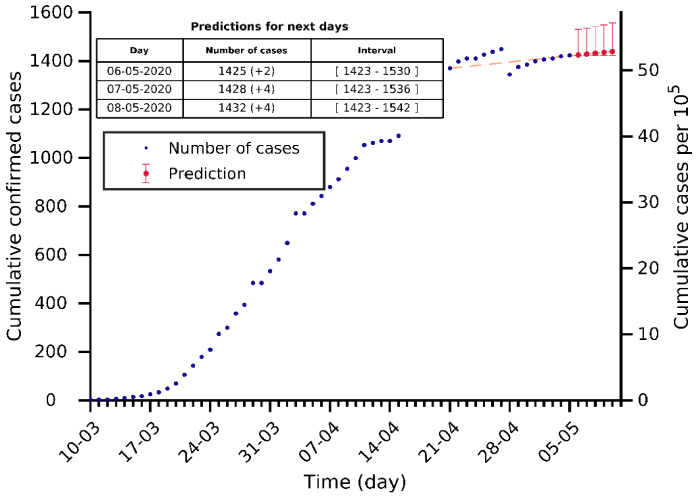


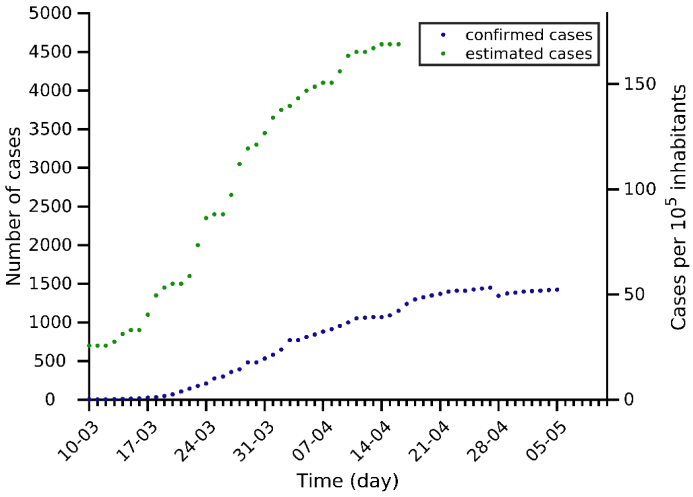


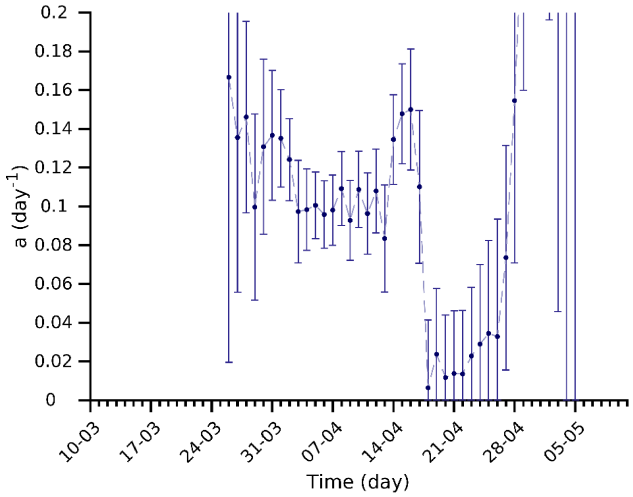


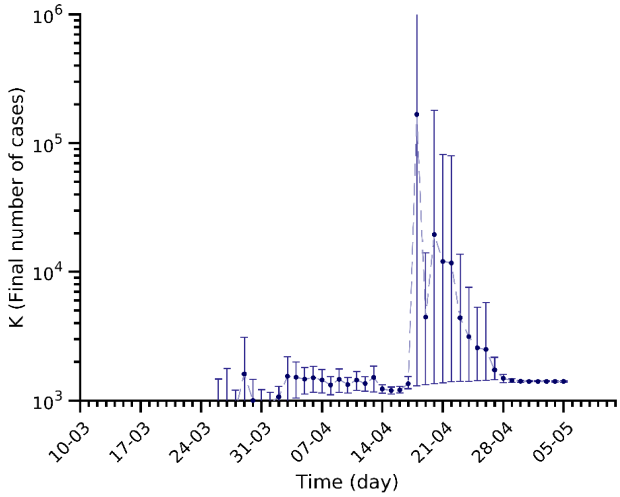


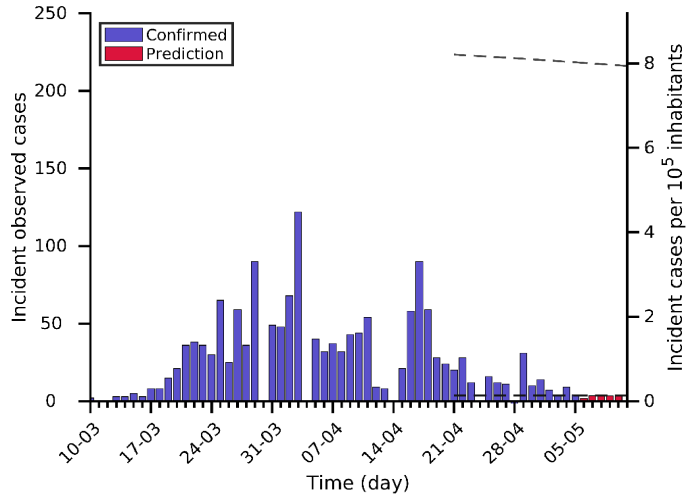
Lithuania 05-05-2020. Population: 2.7M. Current cumulated incidence: 52/10⁵

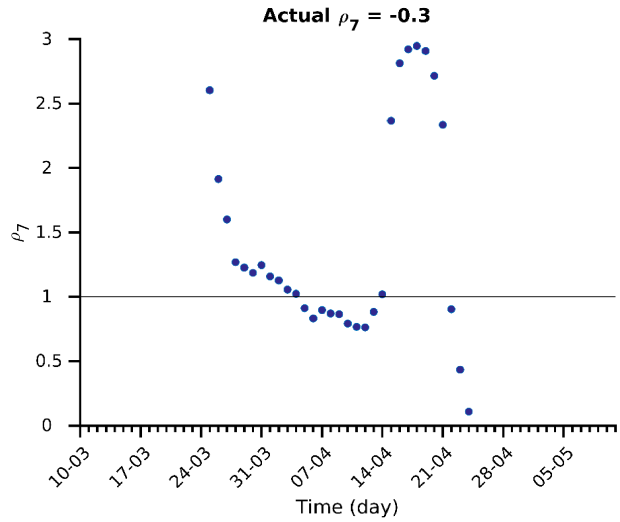


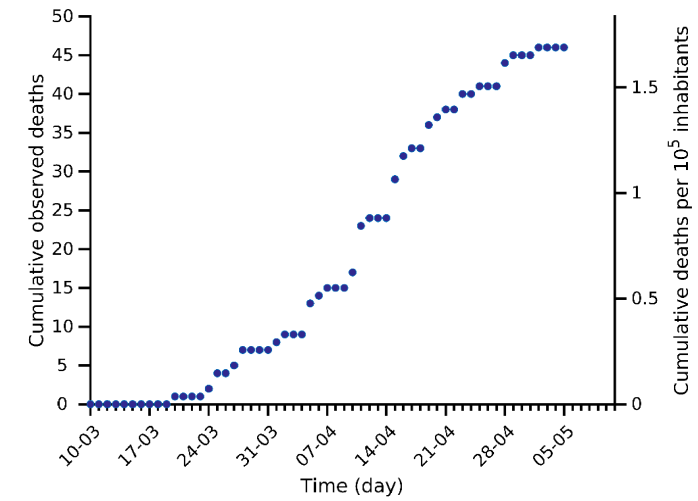


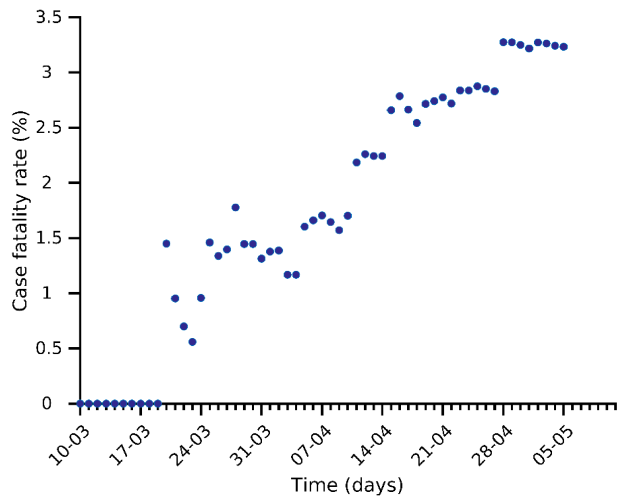




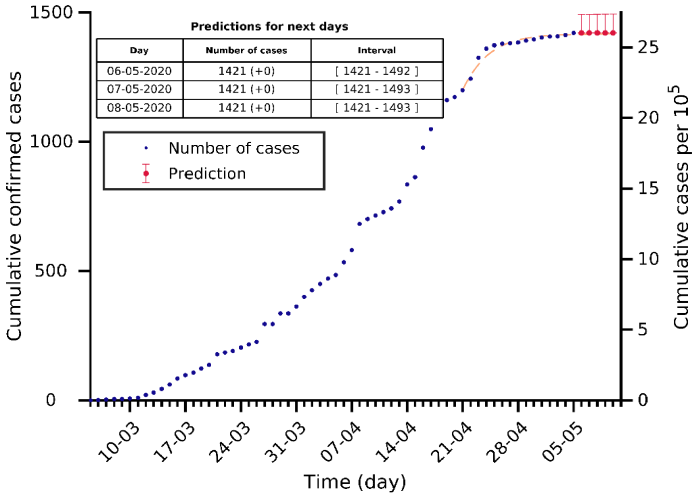


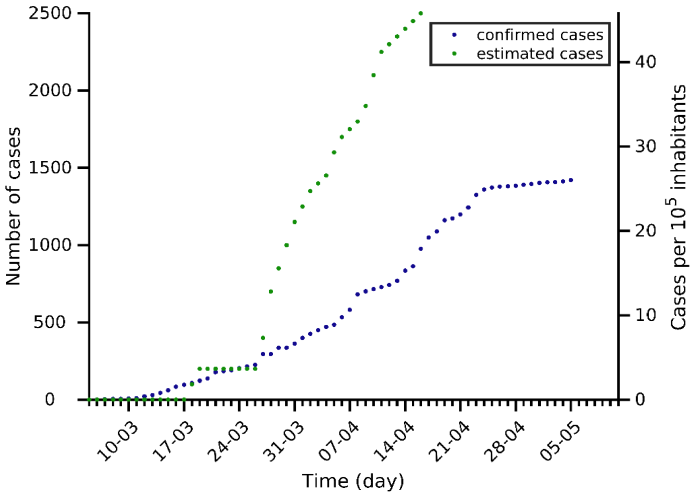


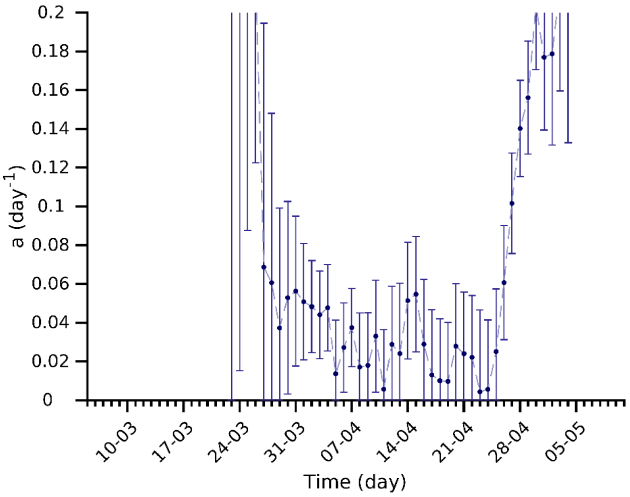


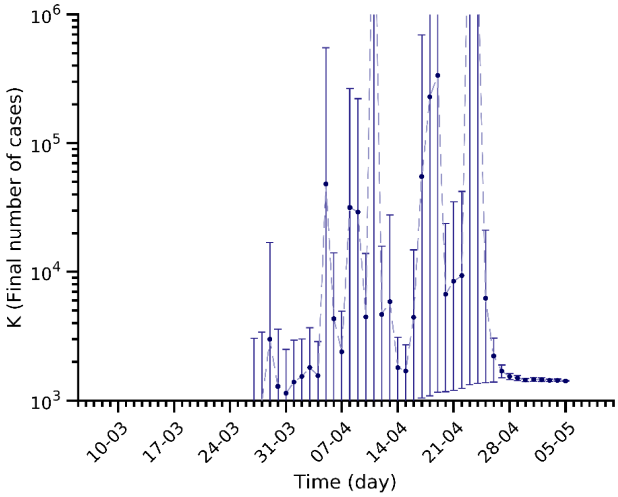


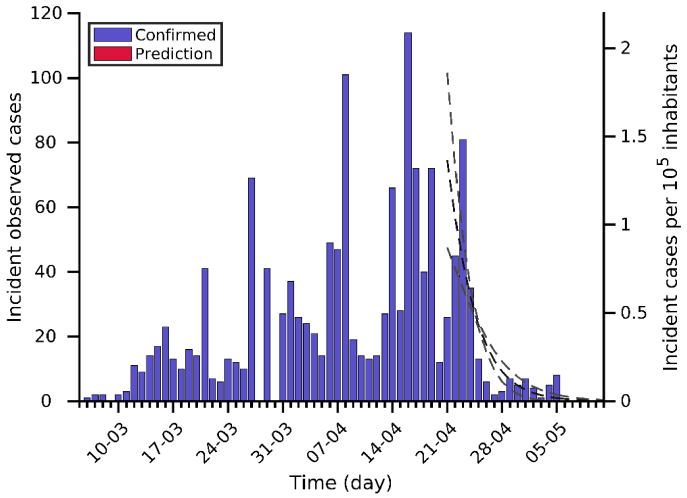
Slovakia 05-05-2020. Population: 5.5M. Current cumulated incidence: 26/10⁵

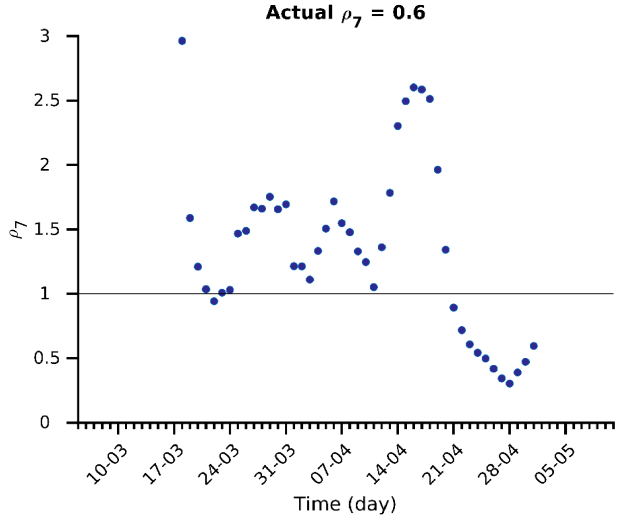


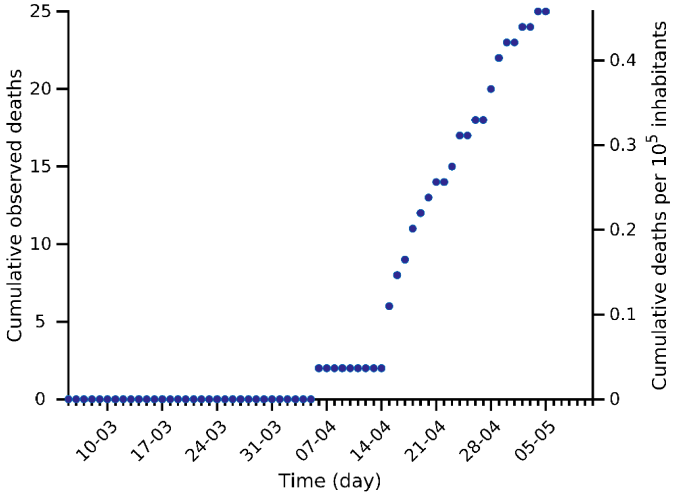


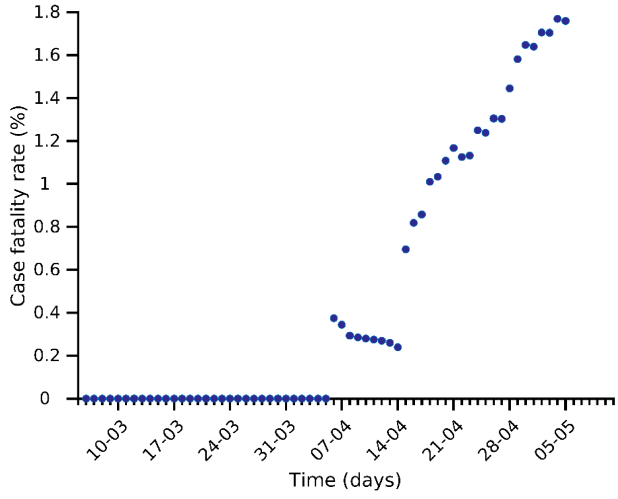




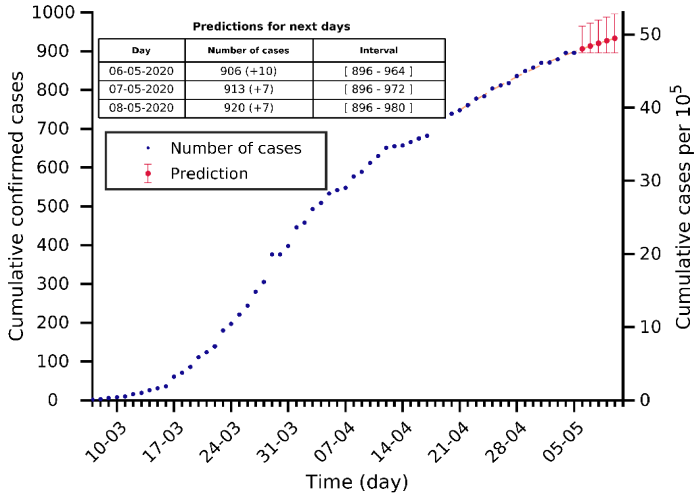


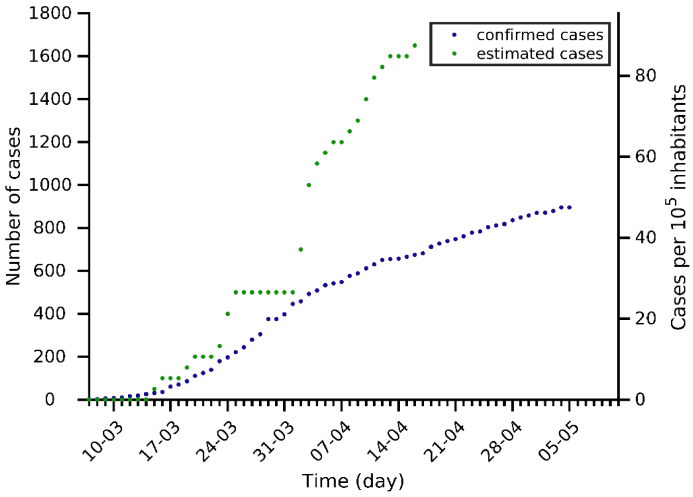


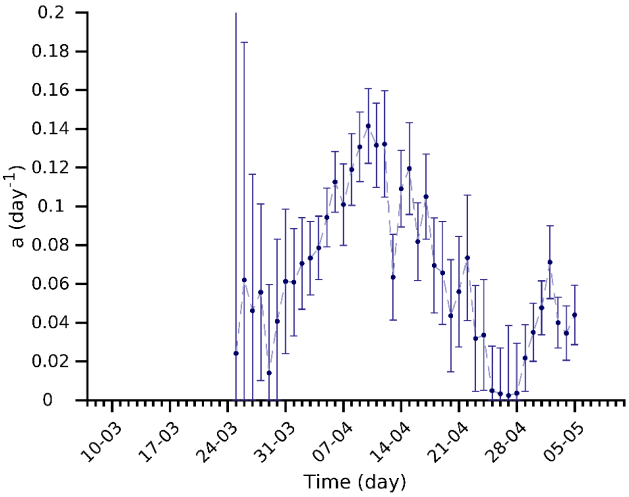


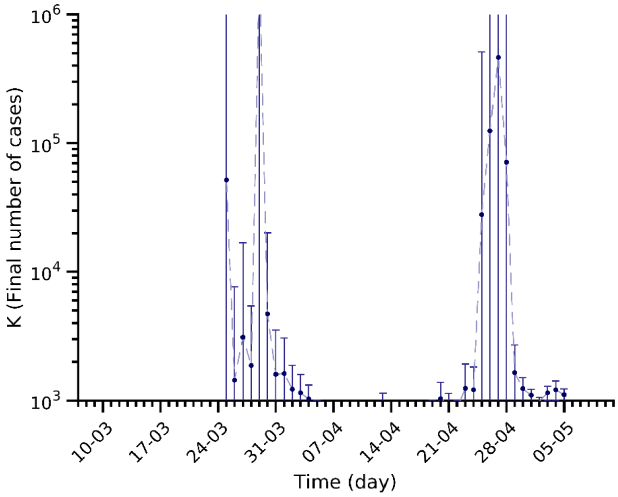


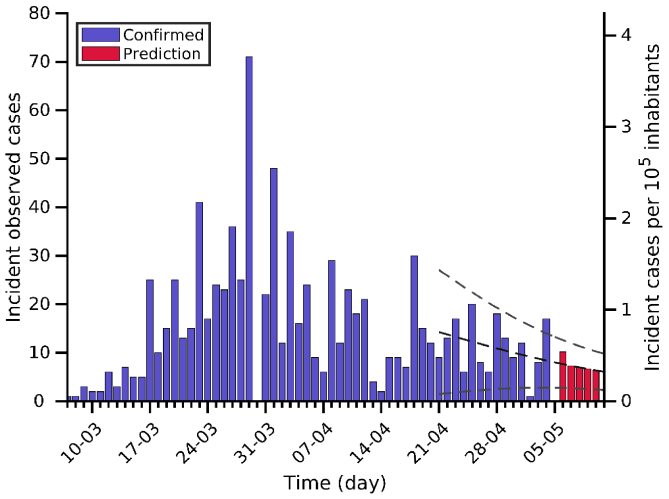
Latvia 05-05-2020. Population: 1.9M. Current cumulated incidence: 48/10^5

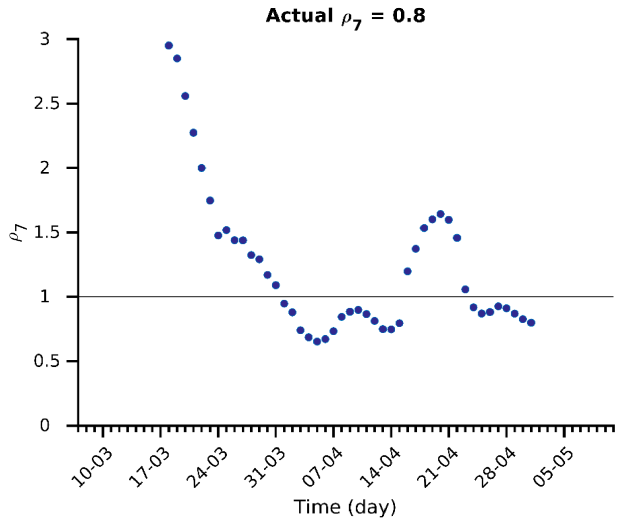


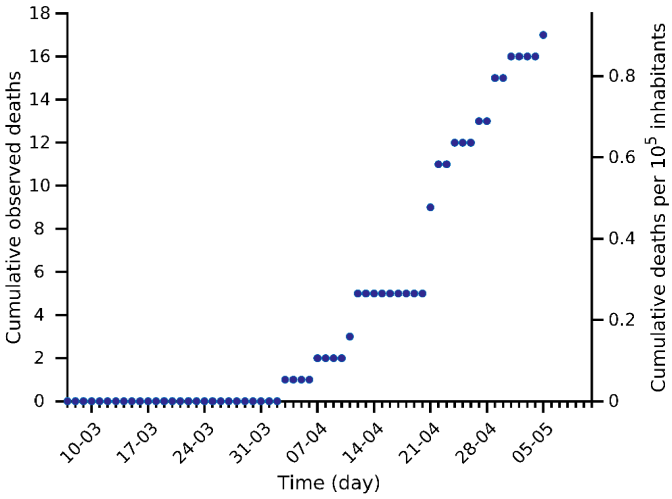


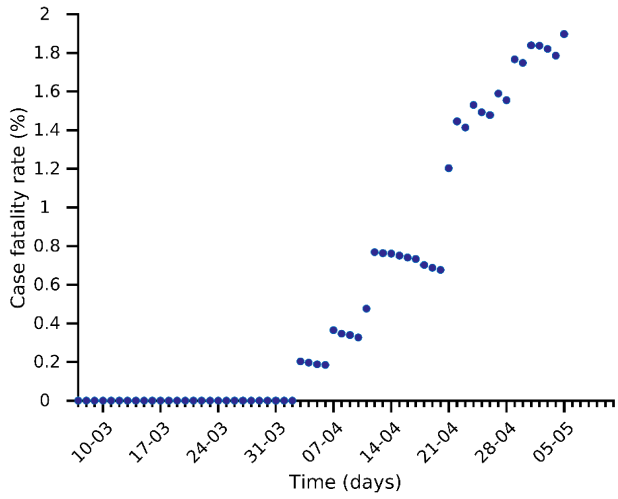




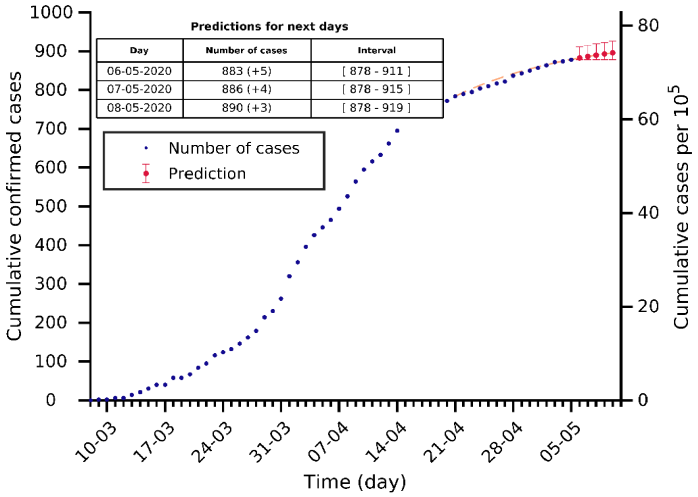


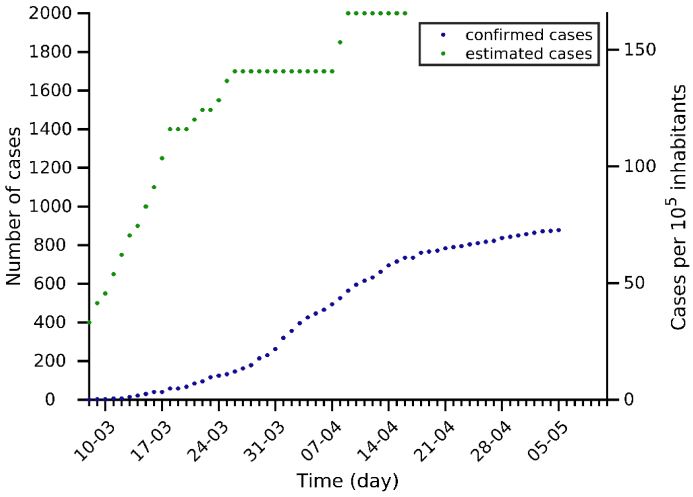


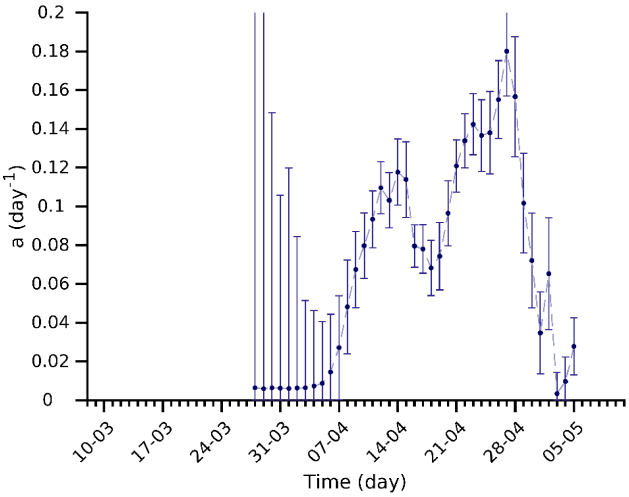


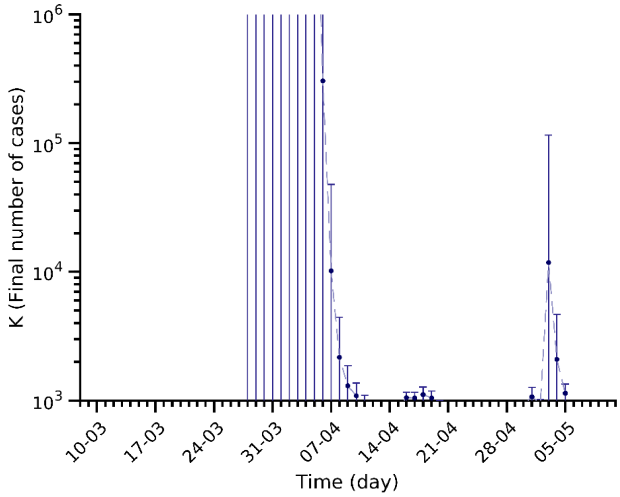


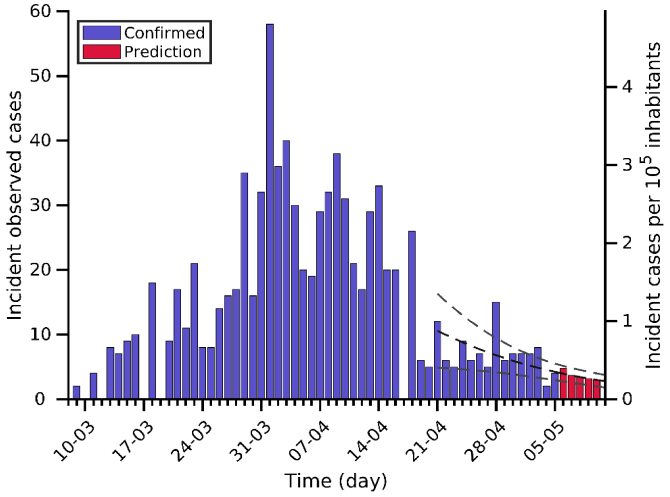
Cyprus 05-05-2020. Population: 1.2M. Current cumulated incidence: 73/10^5

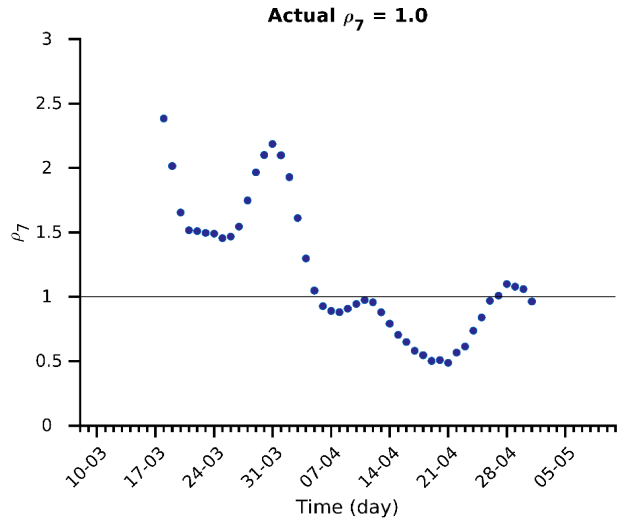


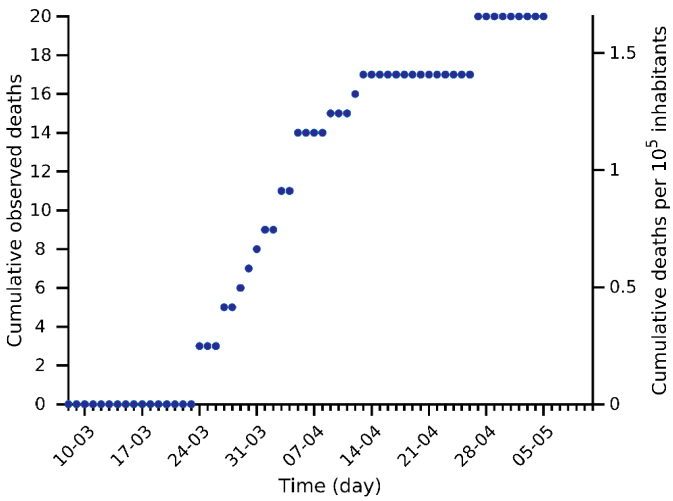


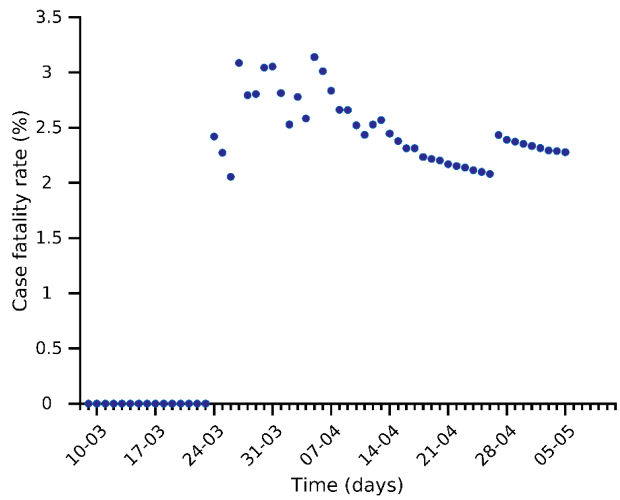




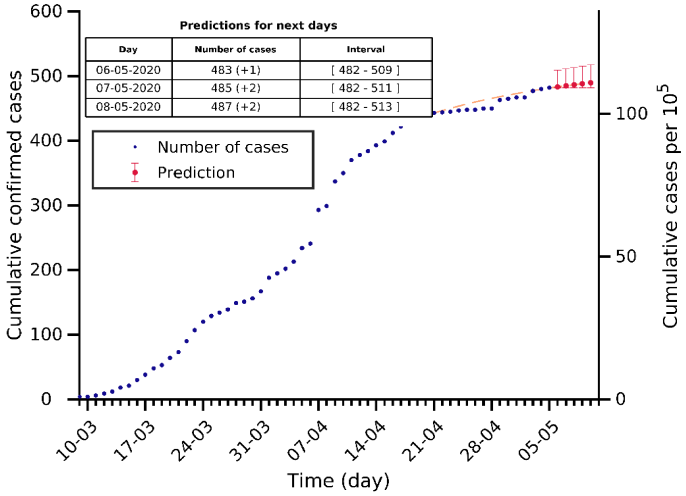


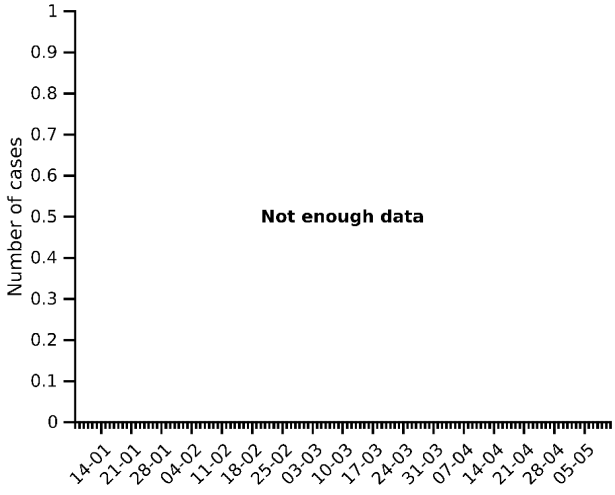


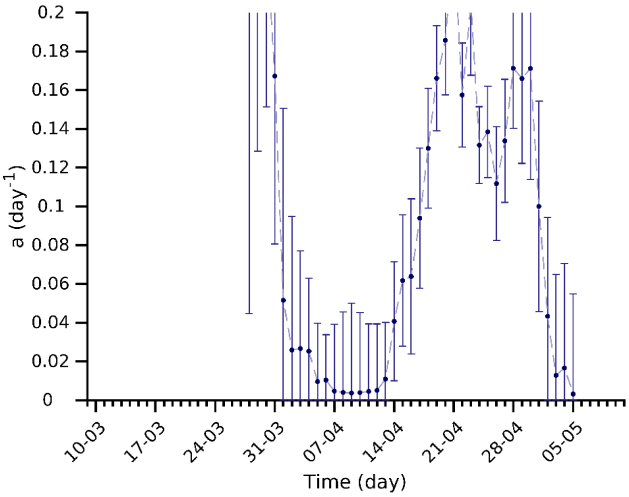


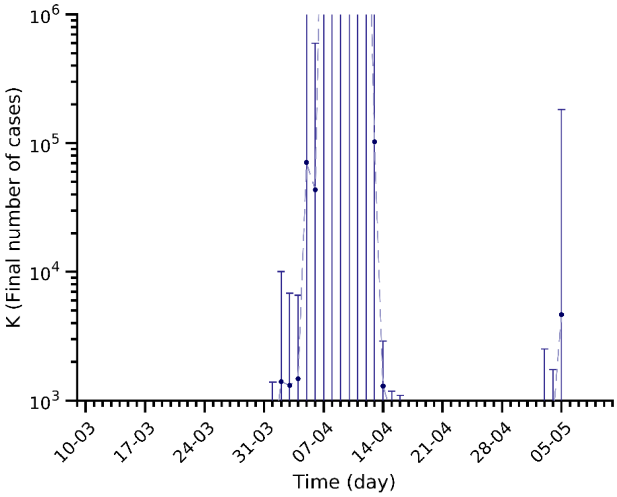


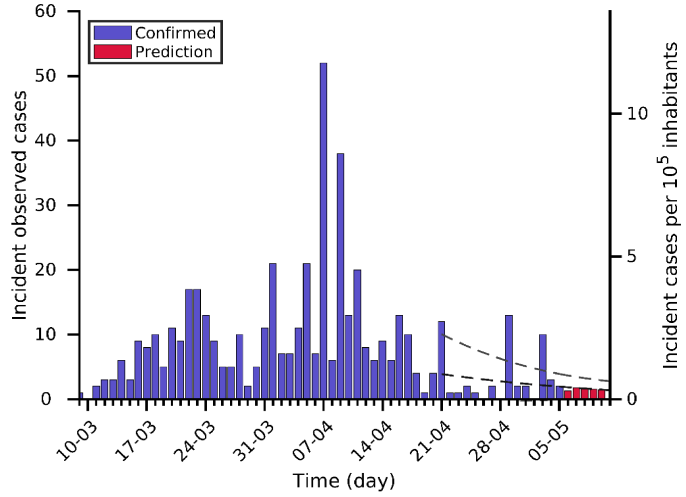
Malta 05-05-2020. Population: 0.4M. Current cumulated incidence: $109/10^5$

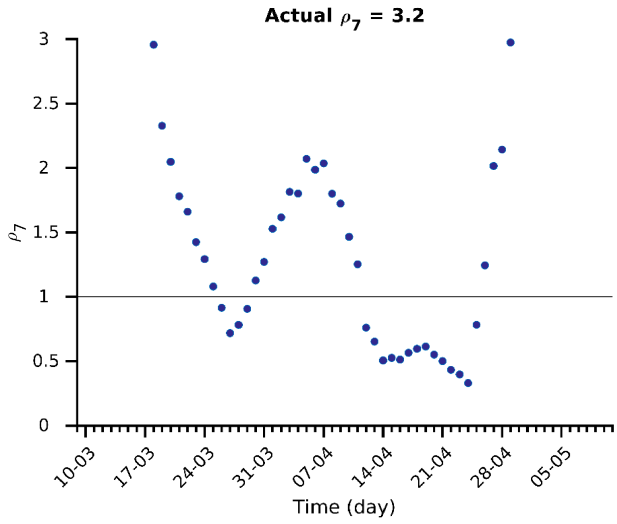


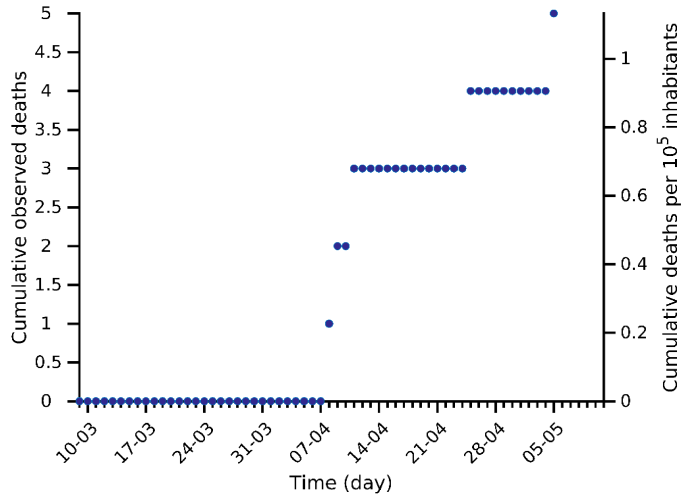


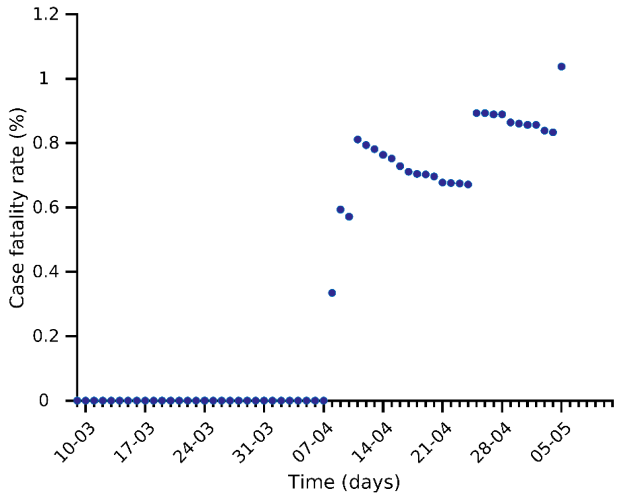








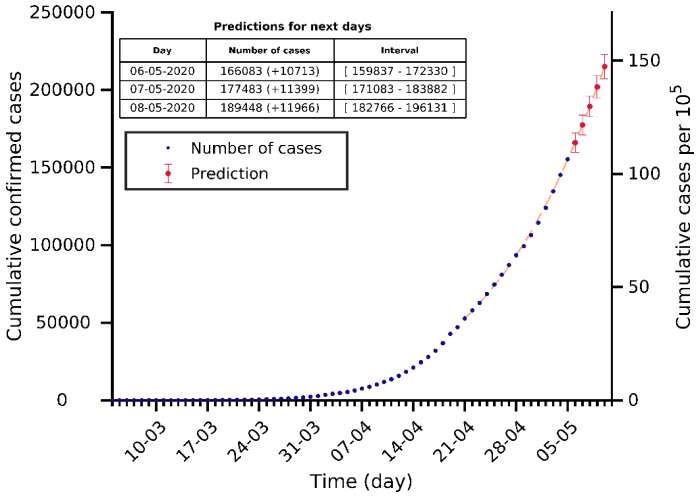


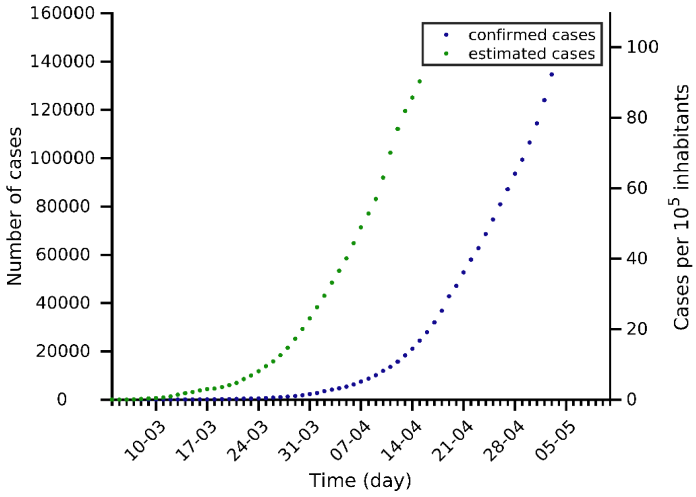


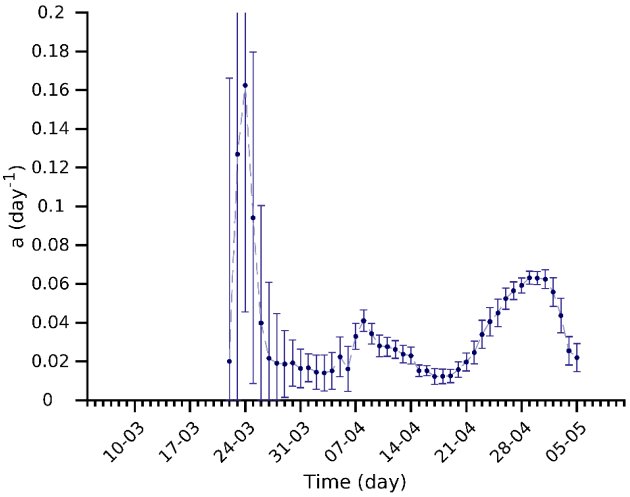
(2) Analysis and prediction of COVID-19 for other countries

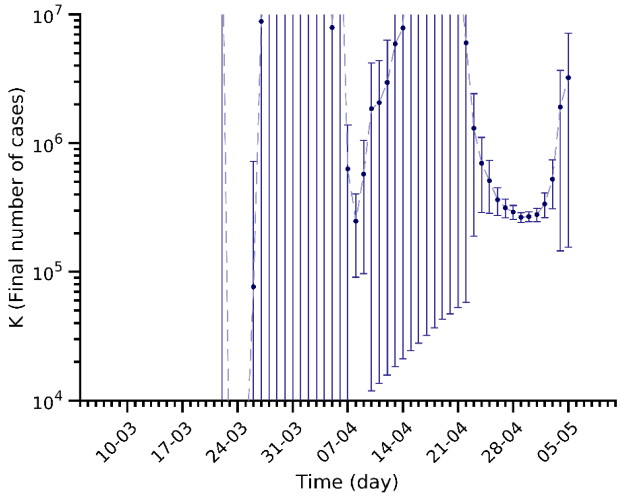
Data obtained from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases

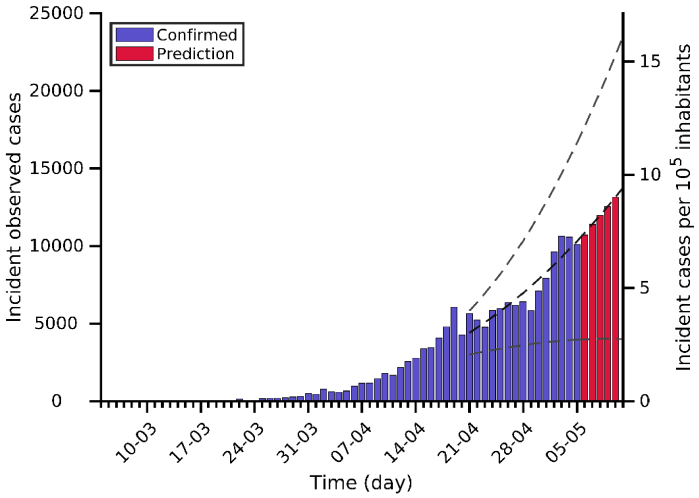
Russia 05-05-2020. Population: 145.9M. Current cumulated incidence: $106/10^5$

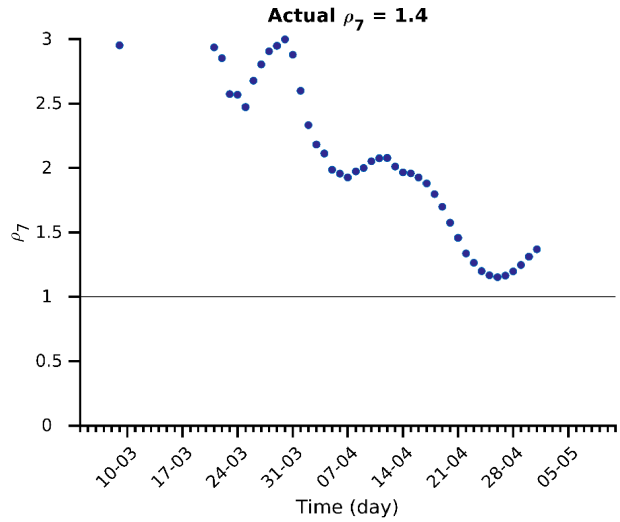


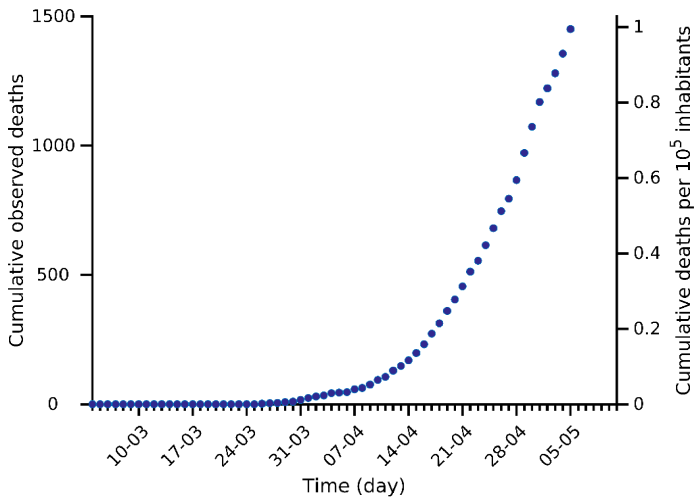


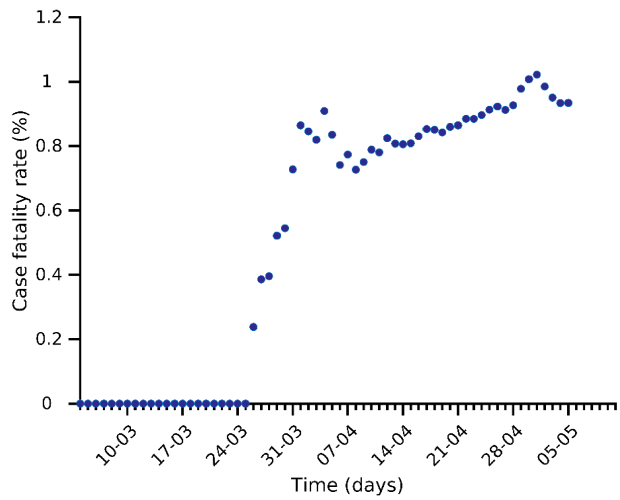




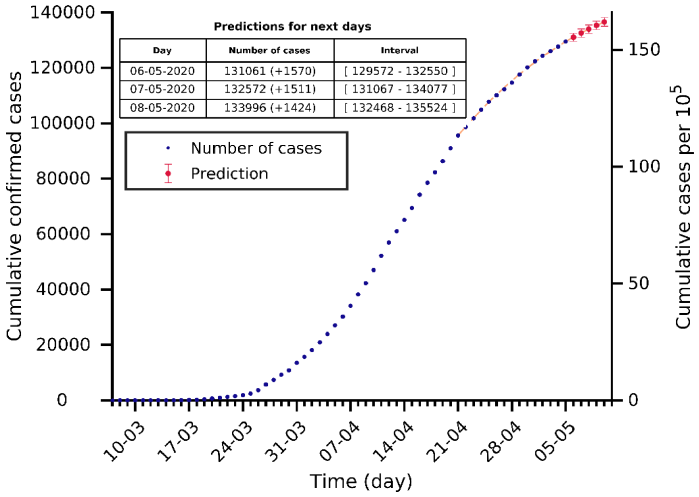


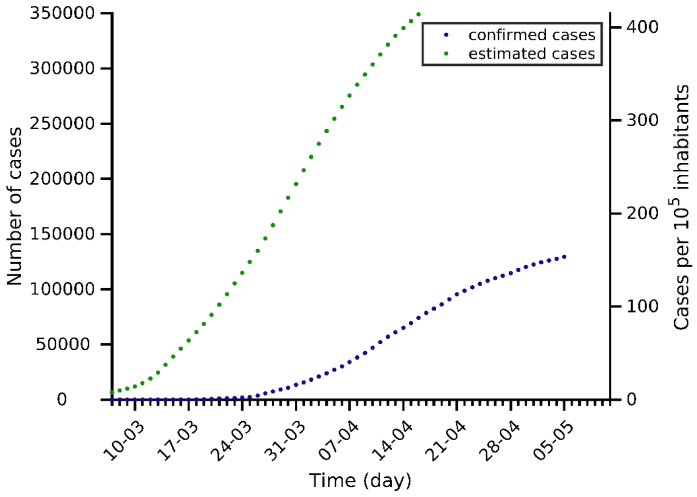


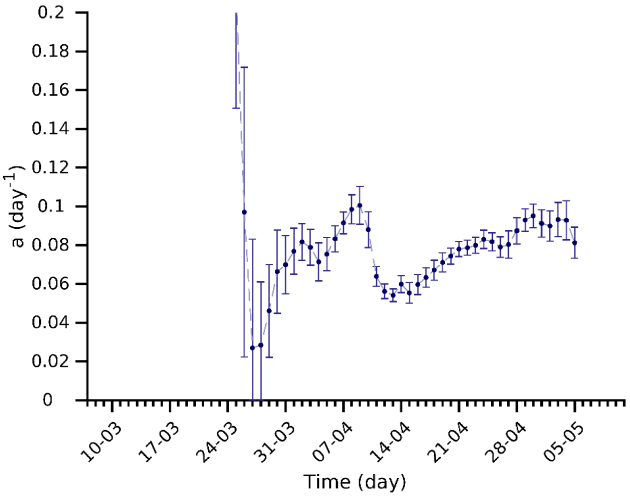


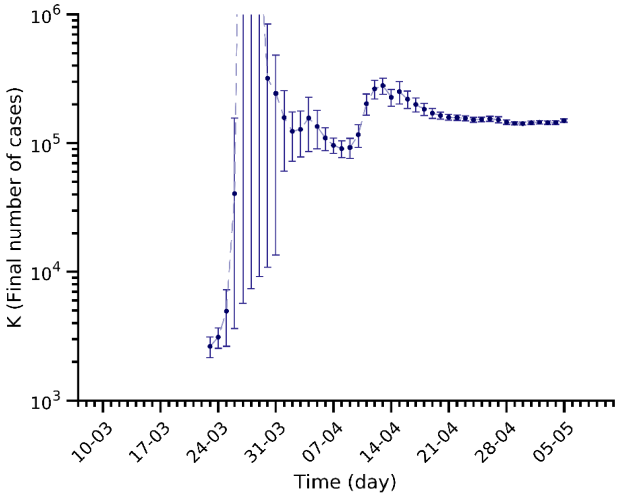


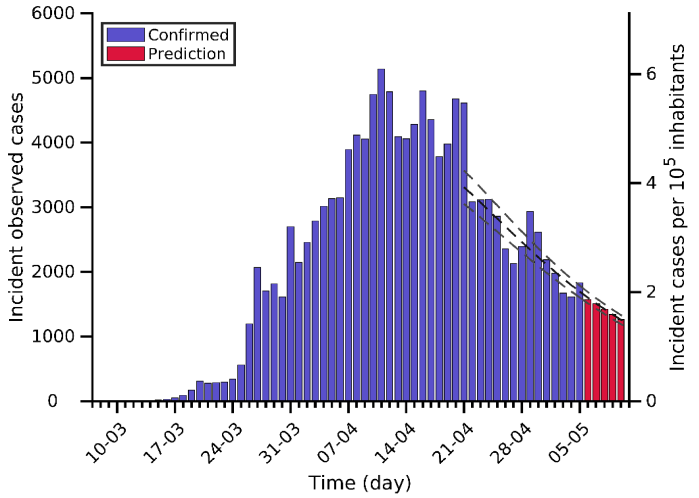
Turkey 05-05-2020. Population: 84.3M. Current cumulated incidence: 154/10^5

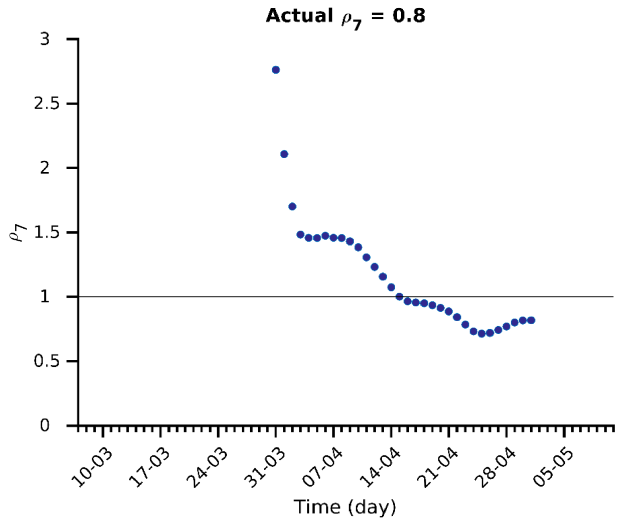


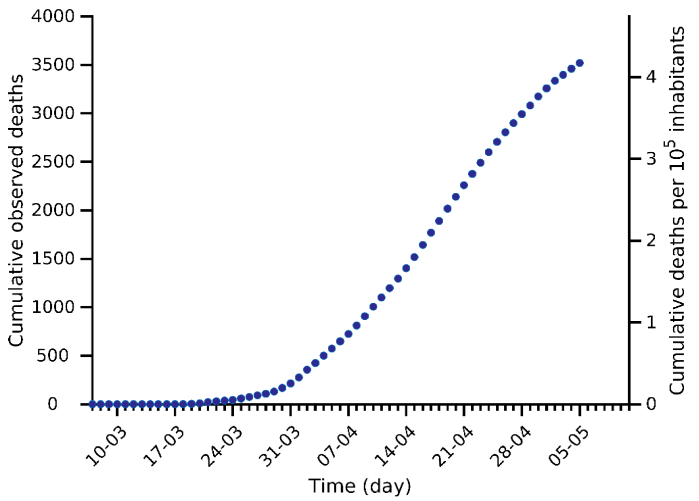


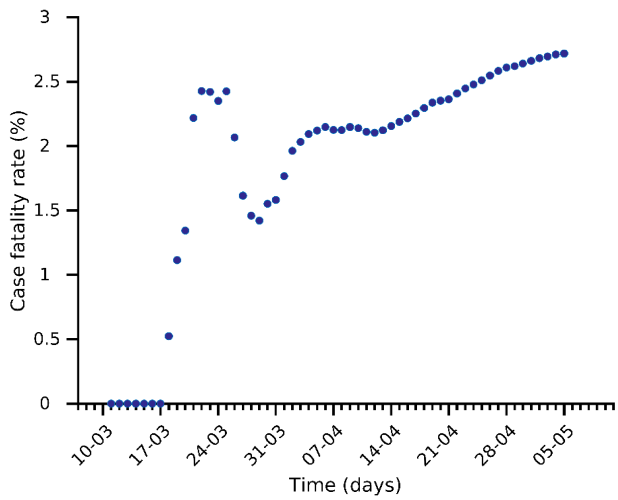




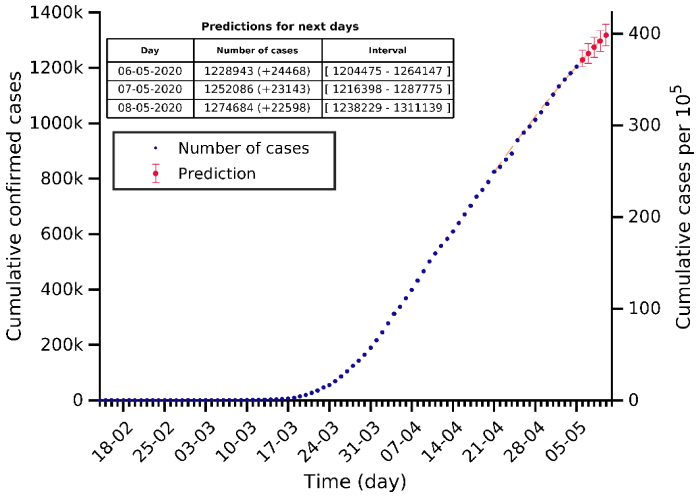


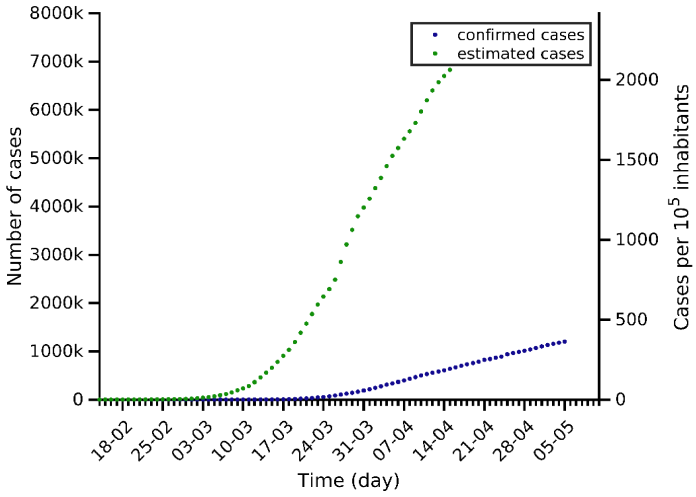


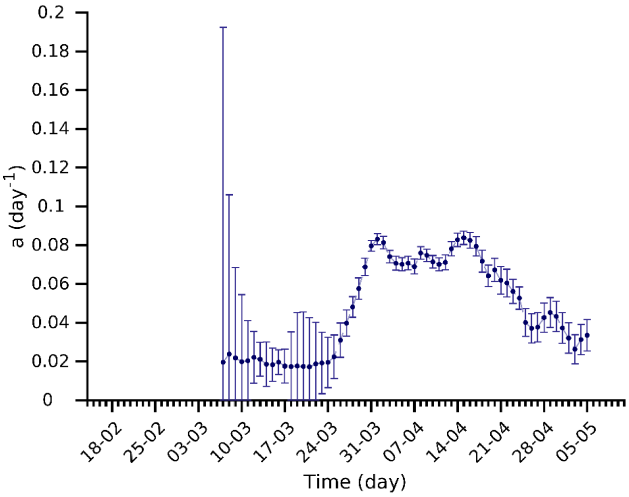


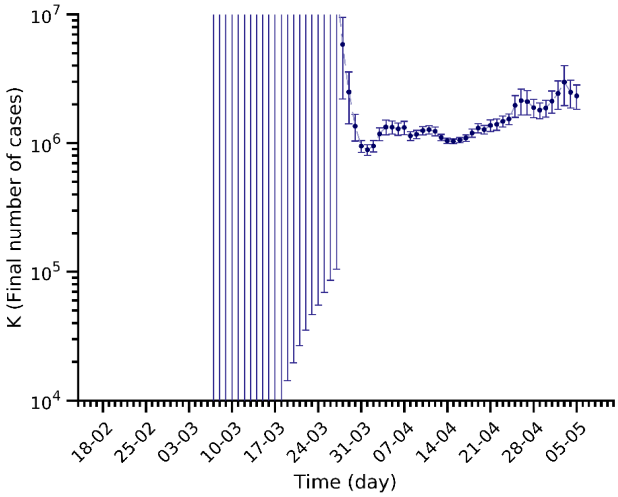


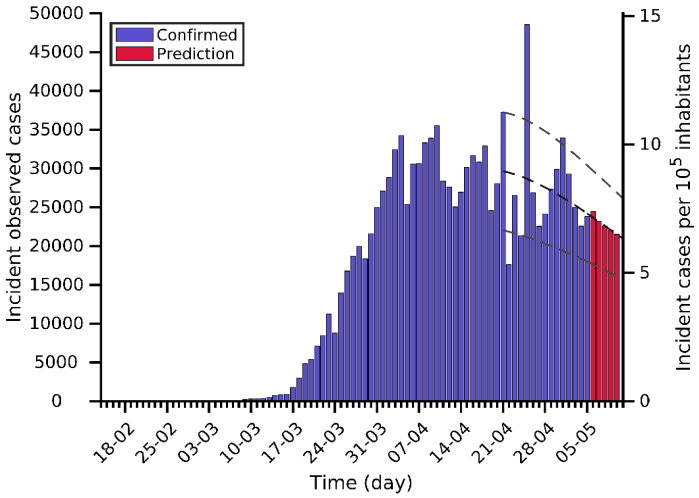
USA 05-05-2020. Population: 331.0M. Current cumulated incidence: 364/10^5

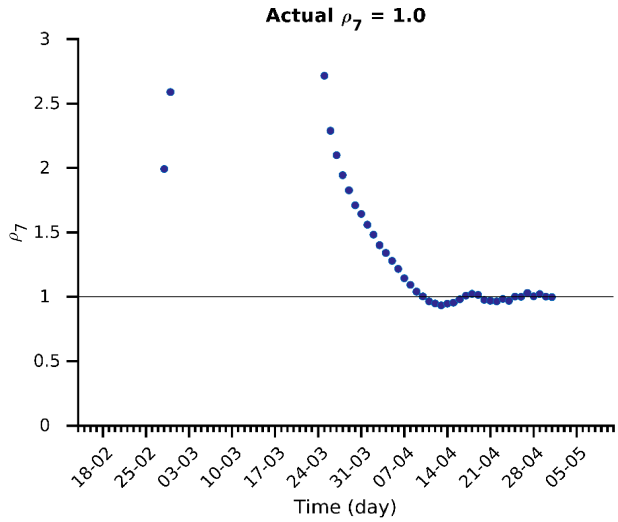


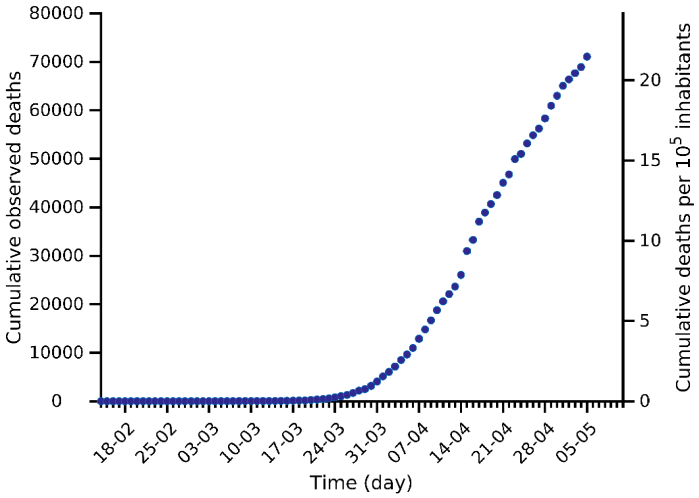


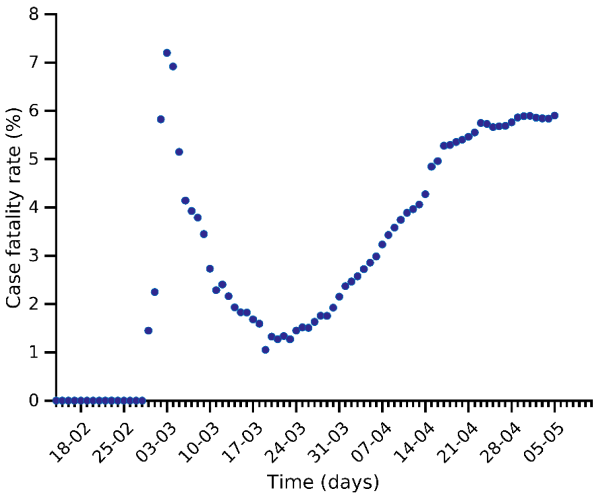




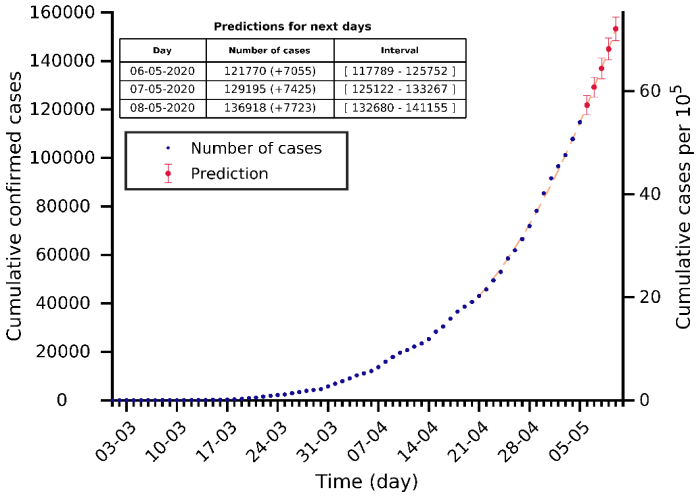


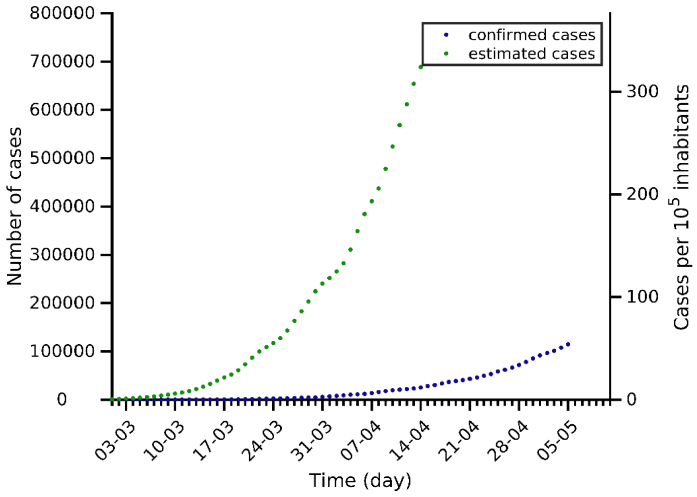


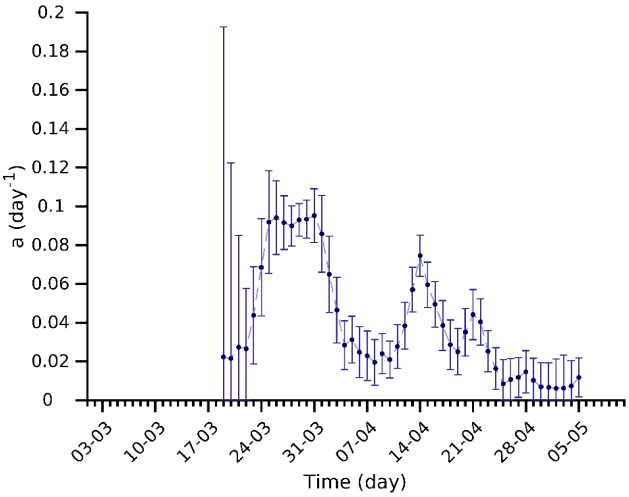


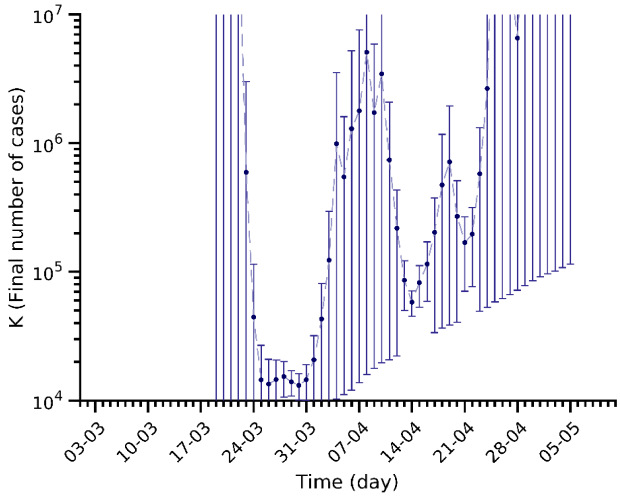


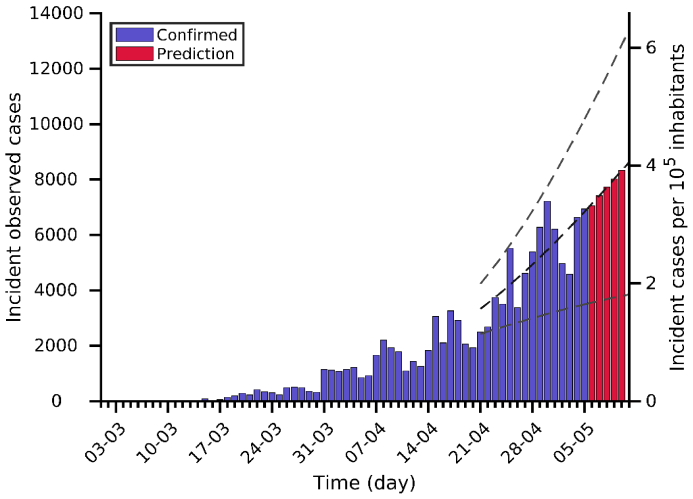
Brazil 05-05-2020. Population: 212.6M. Current cumulated incidence: $54/10^5$

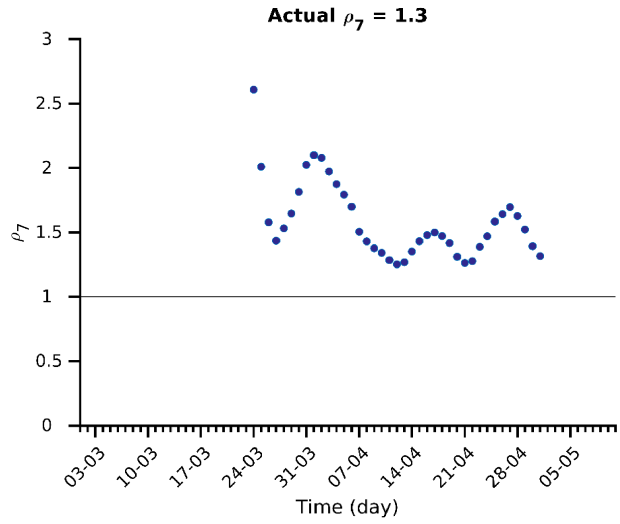


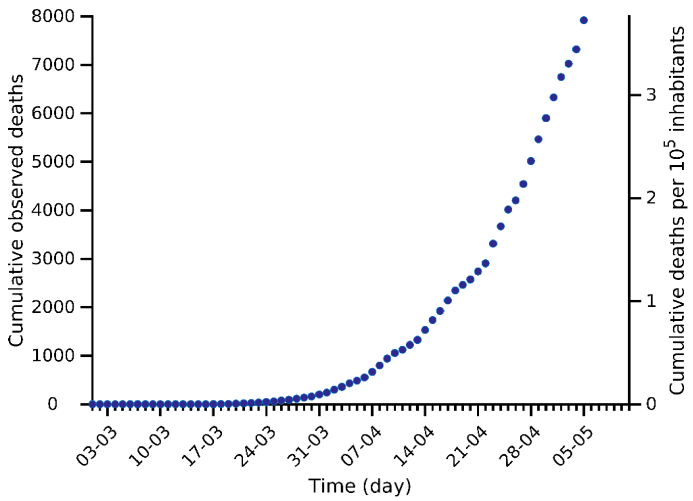


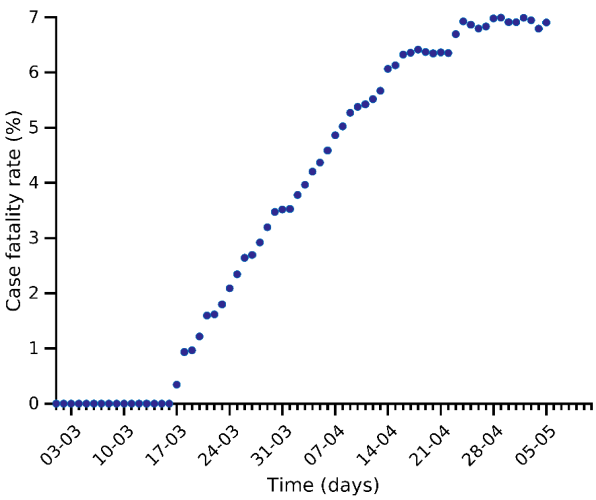




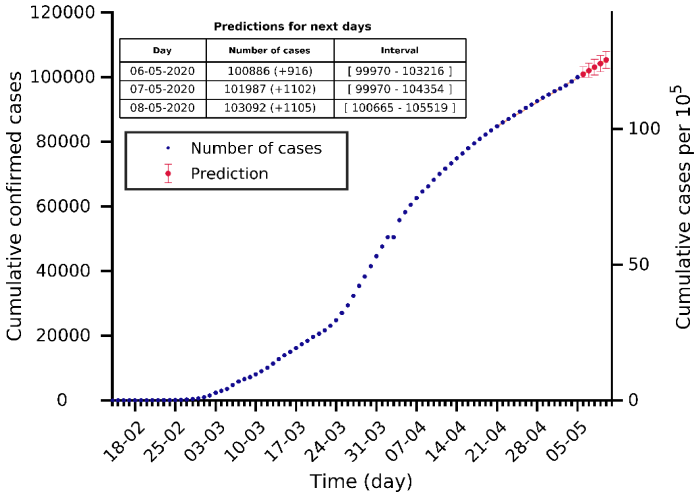


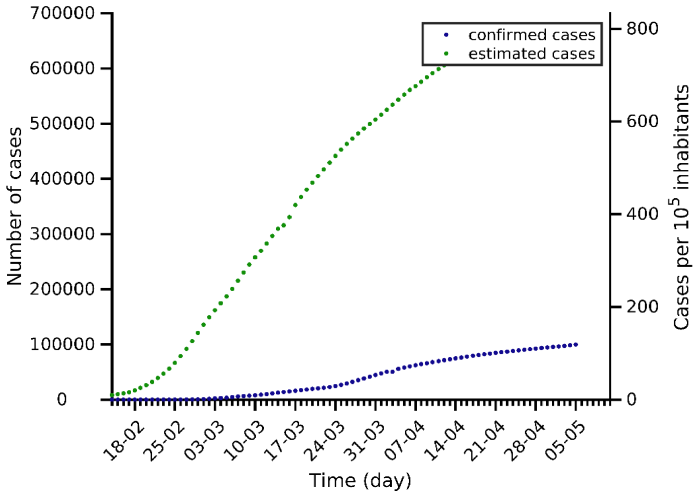


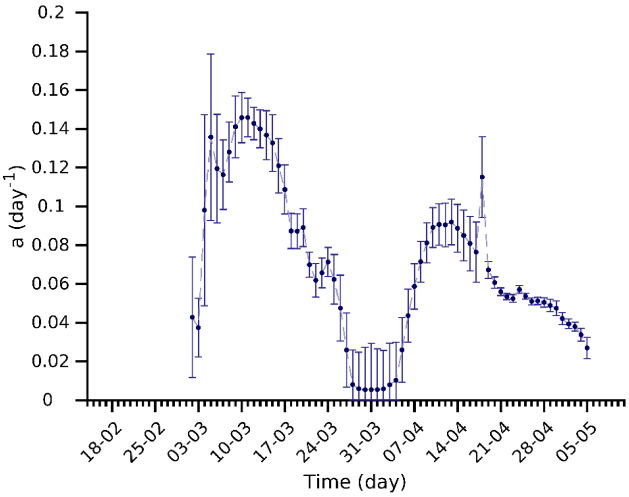


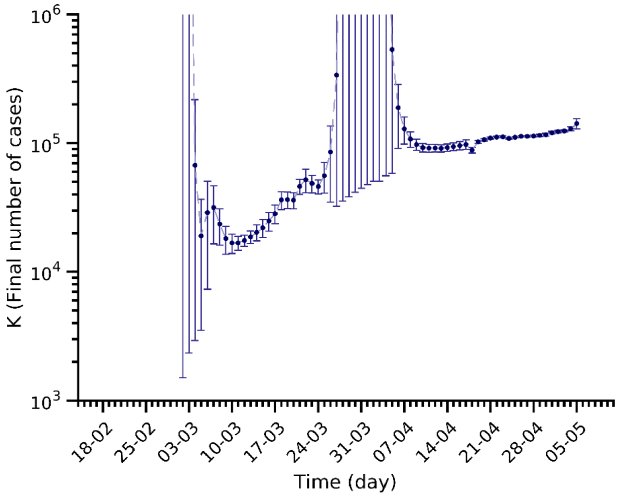


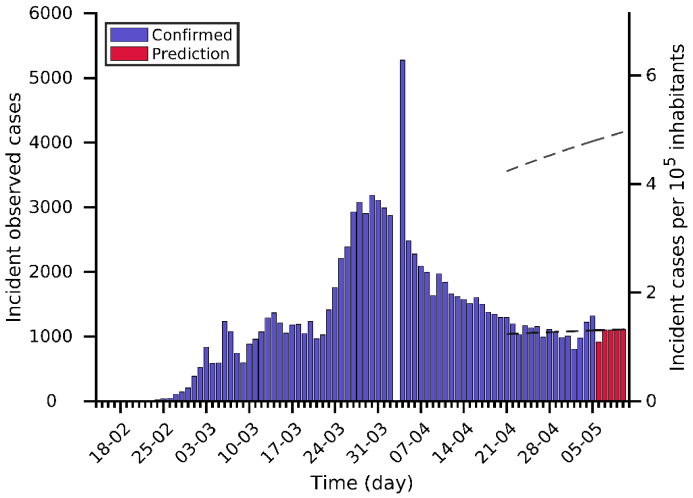
Iran 05-05-2020. Population: 84.0M. Current cumulated incidence: 119/10^5

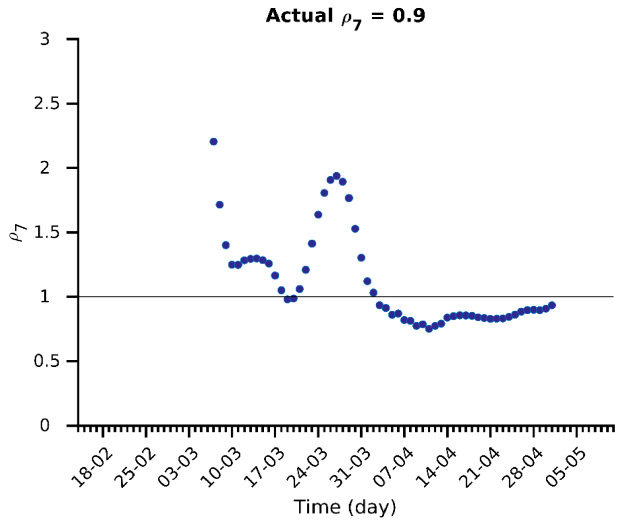


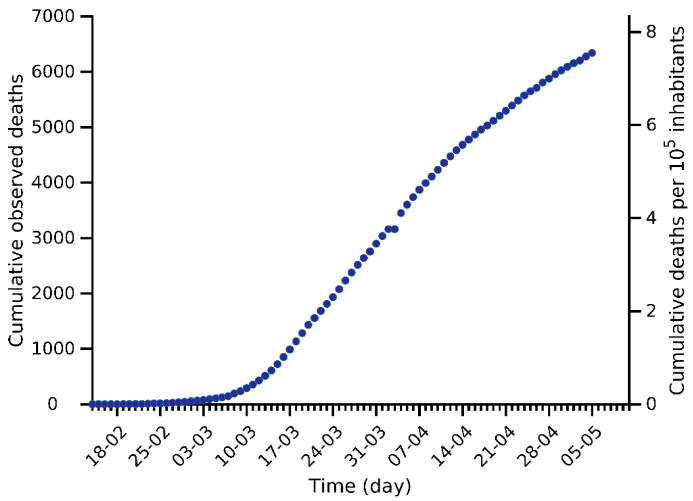


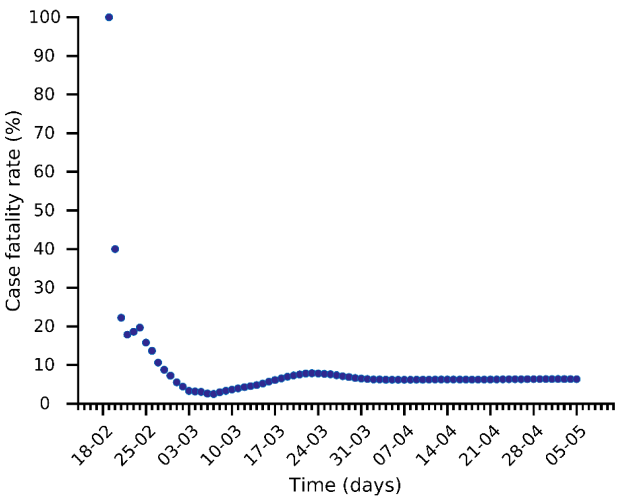




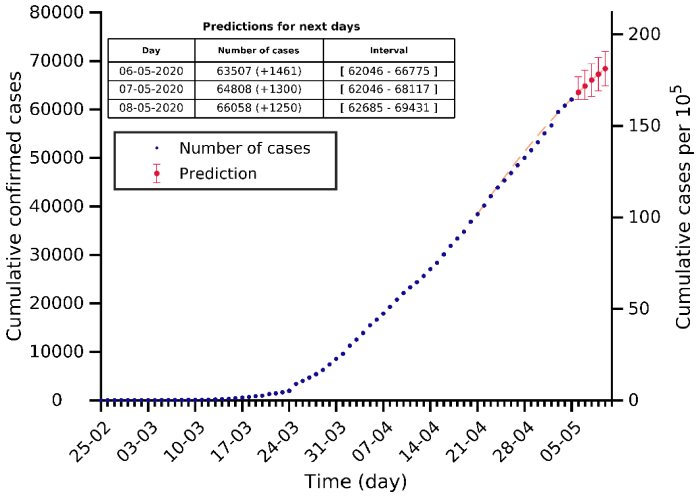


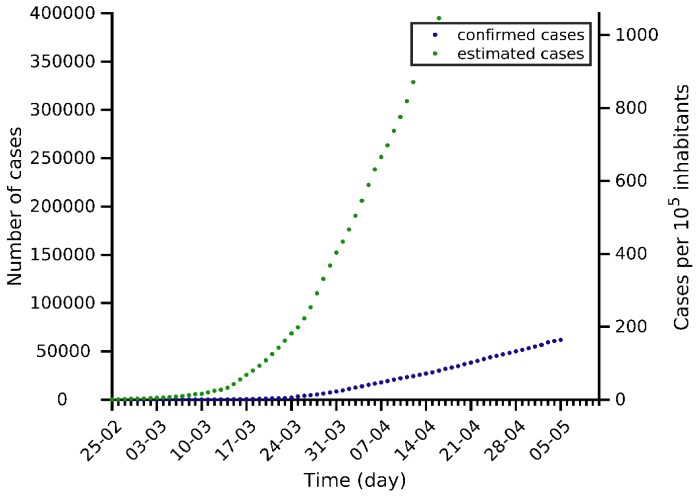


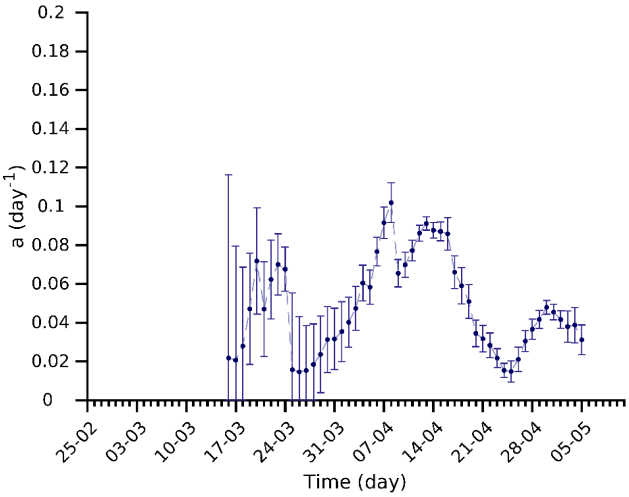


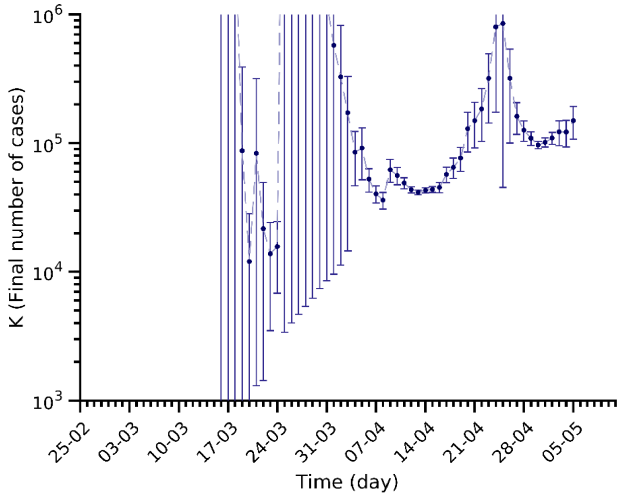


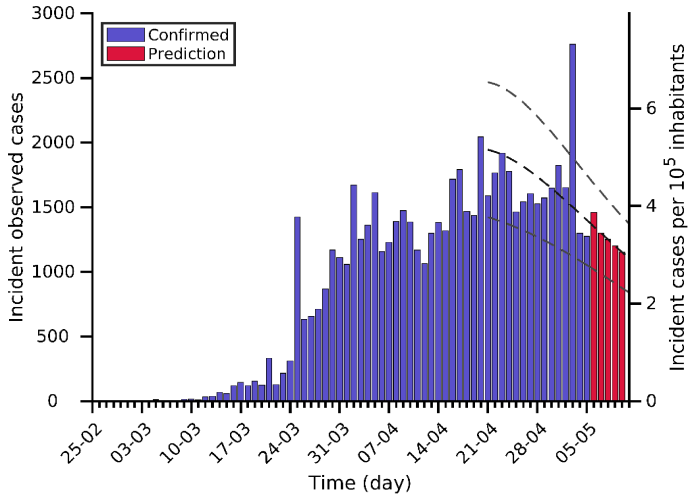
Canada 05-05-2020. Population: 37.7M. Current cumulated incidence: 164/10⁵

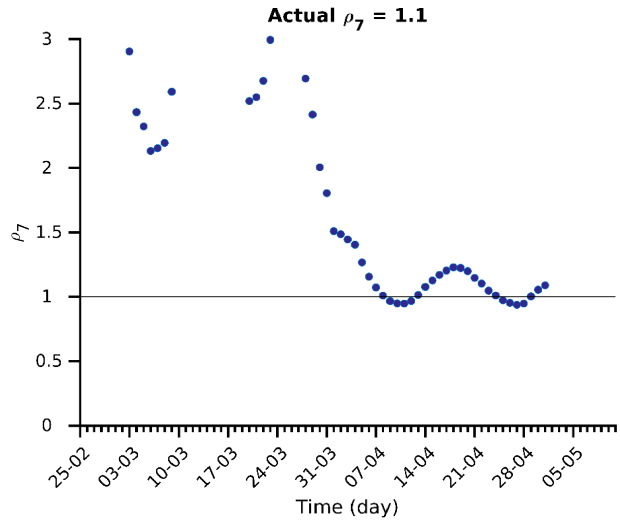


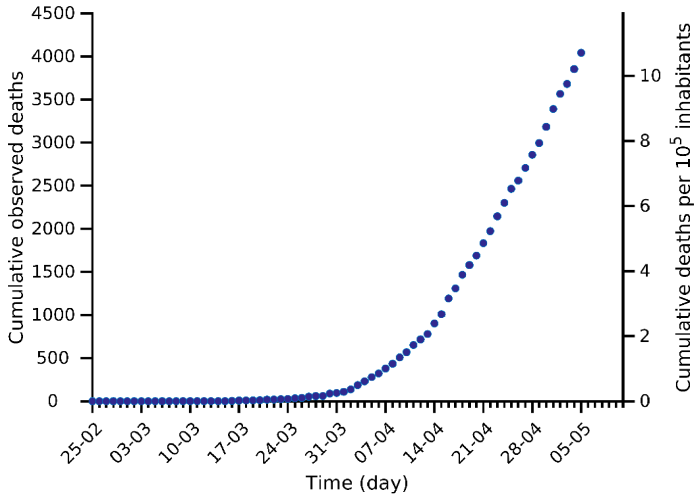


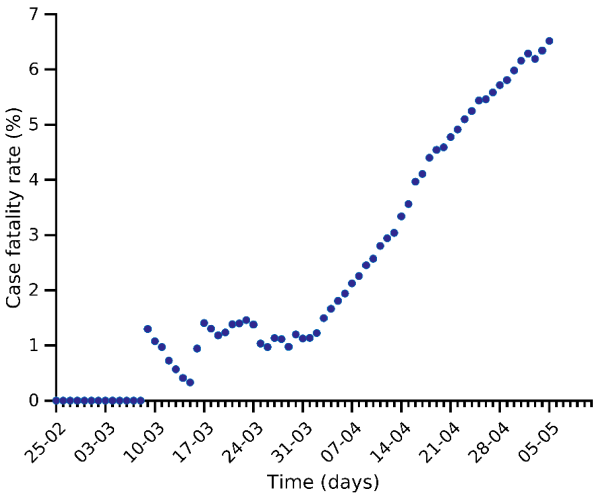




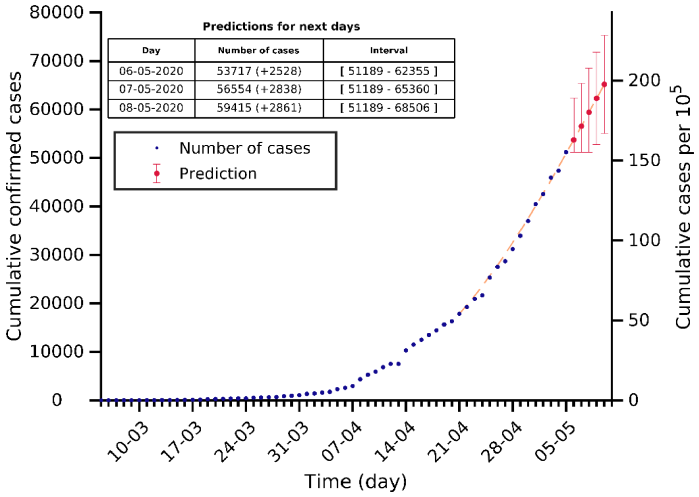


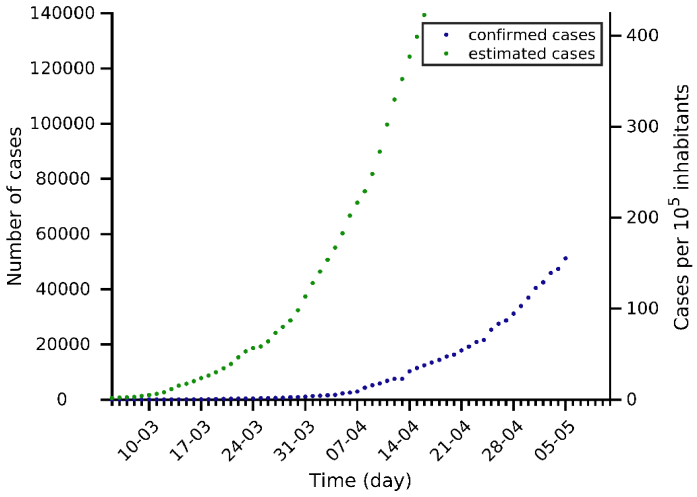


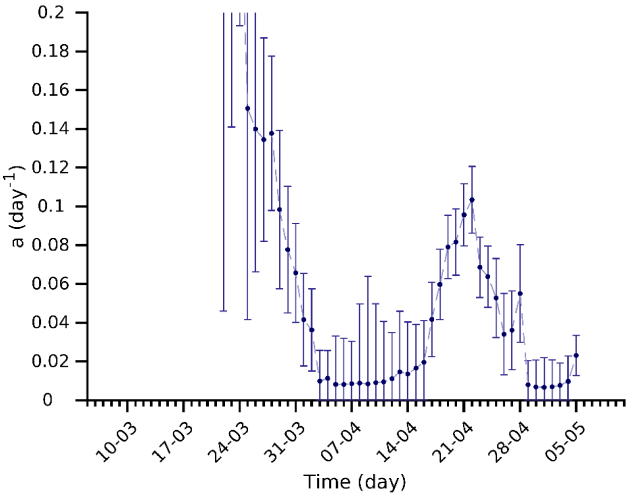


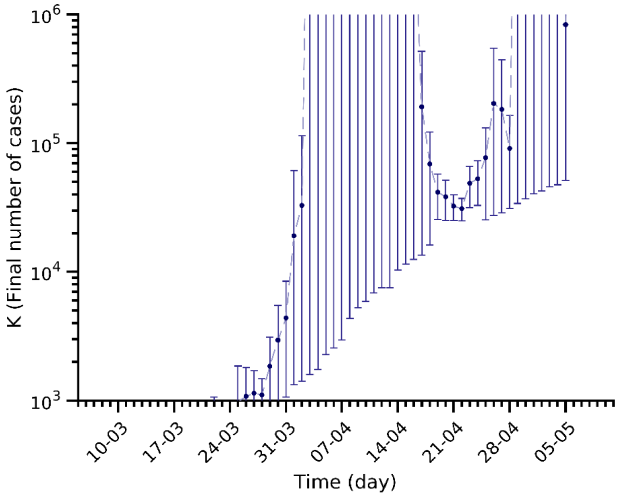


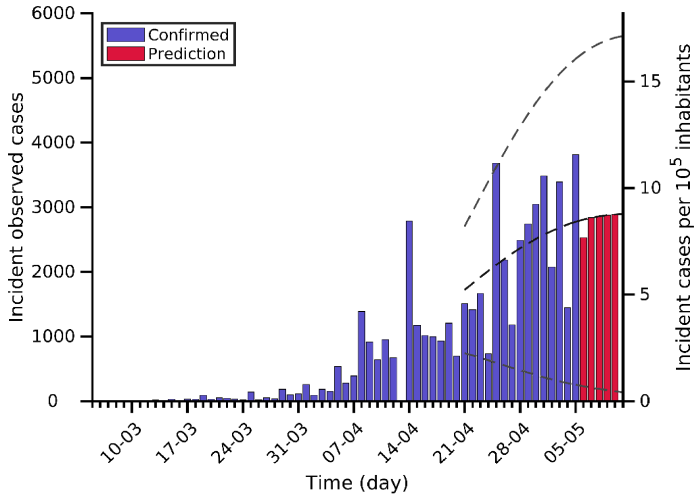
Peru 05-05-2020. Population: 33.0M. Current cumulated incidence: $155/10^5$

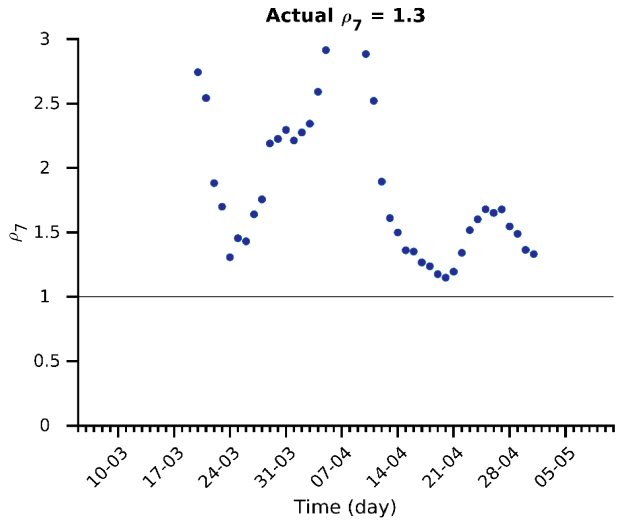


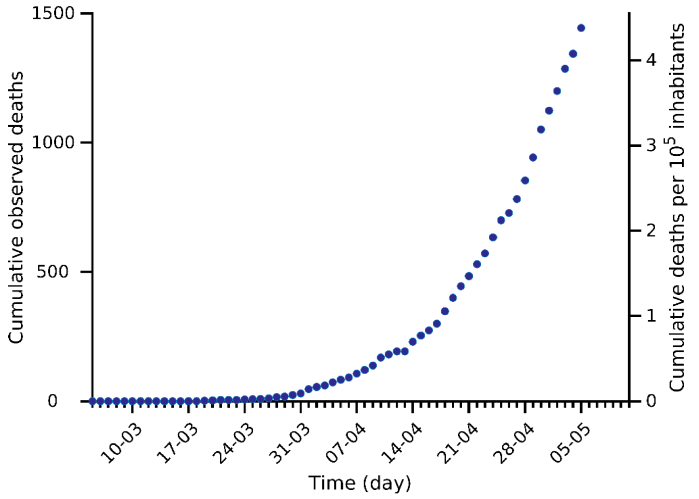


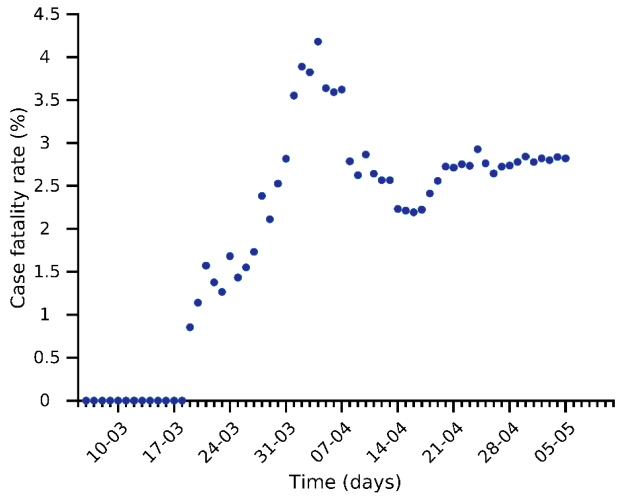




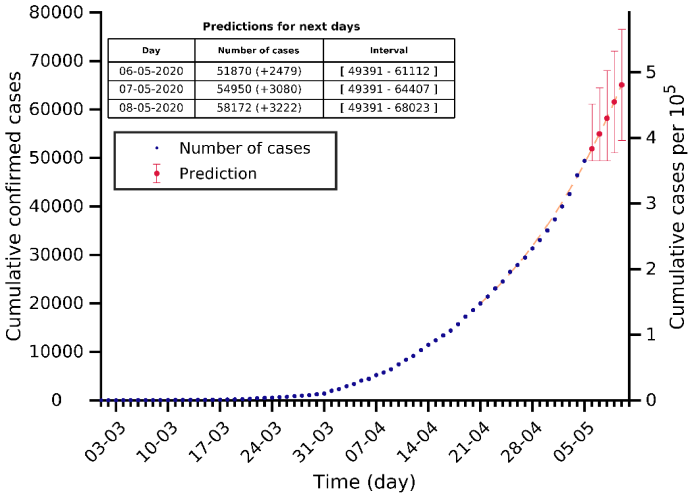


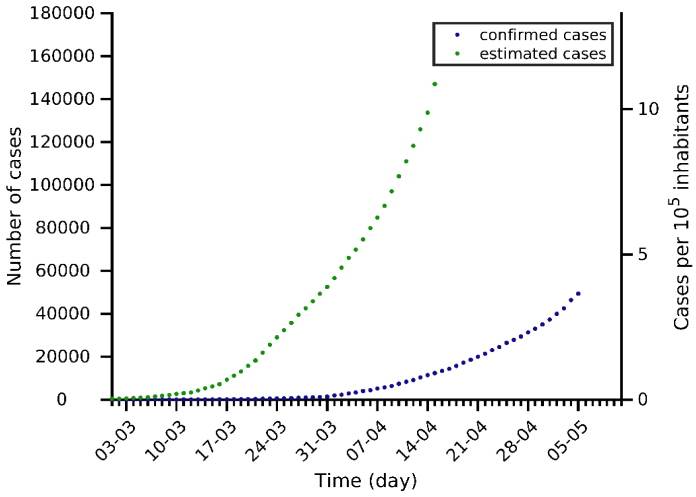


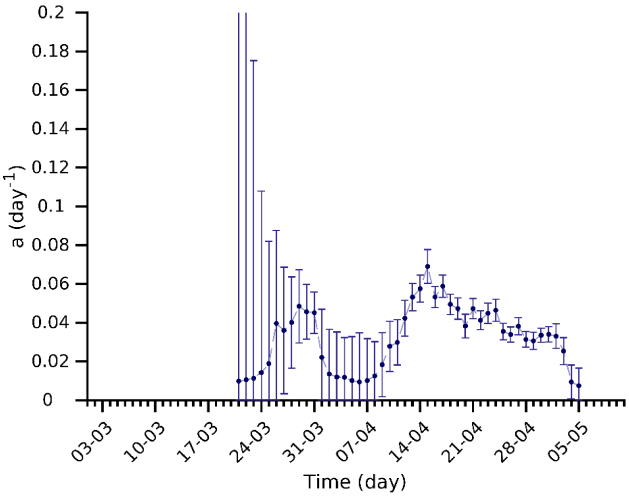


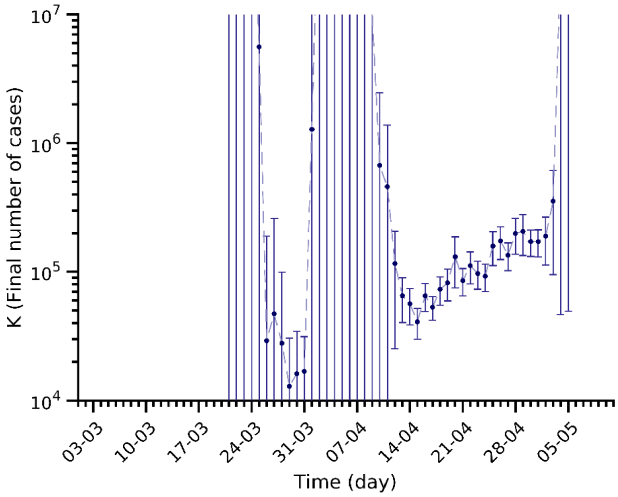


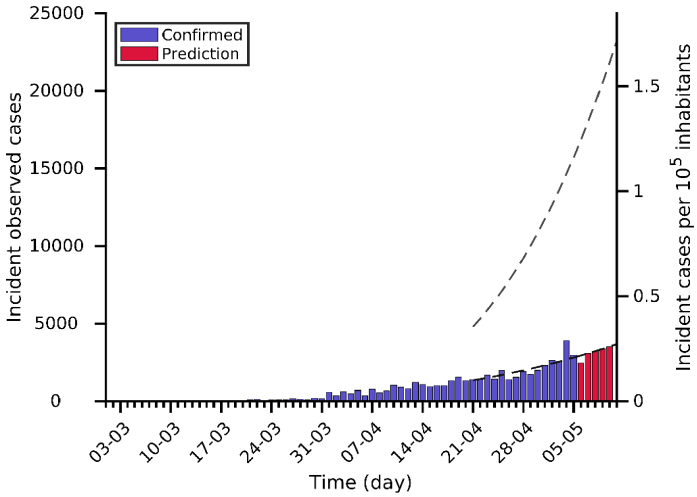
India 05-05-2020. Population: 1353.0M. Current cumulated incidence: $4/10^5$

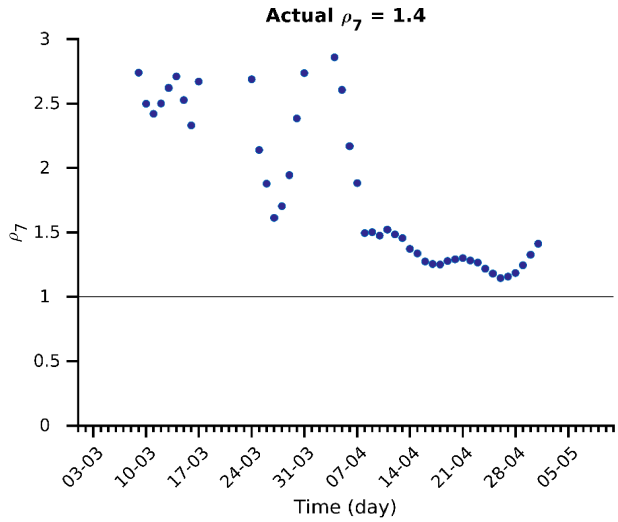


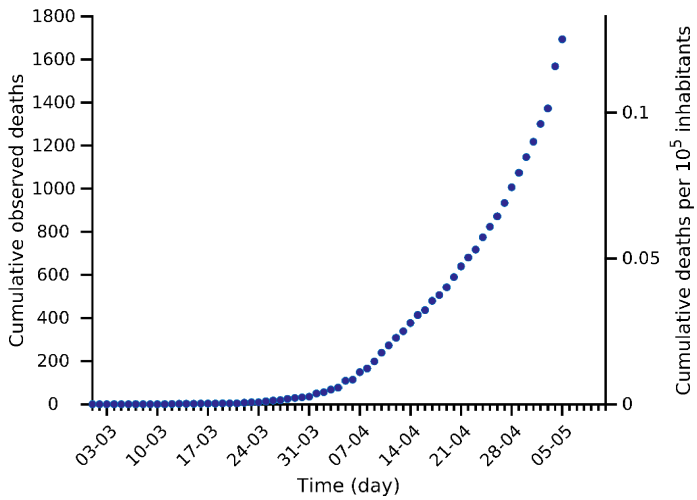


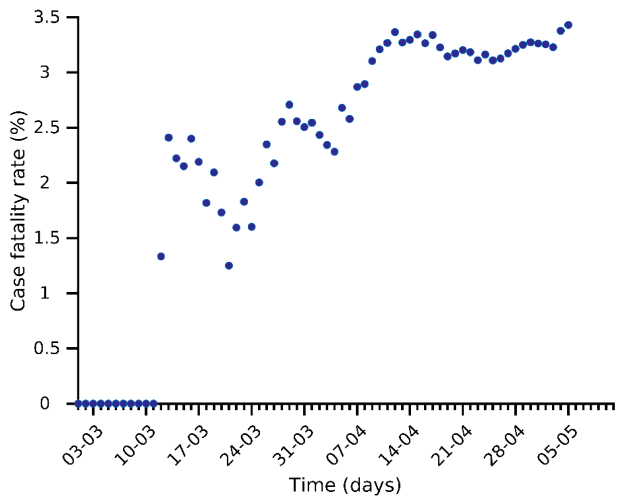




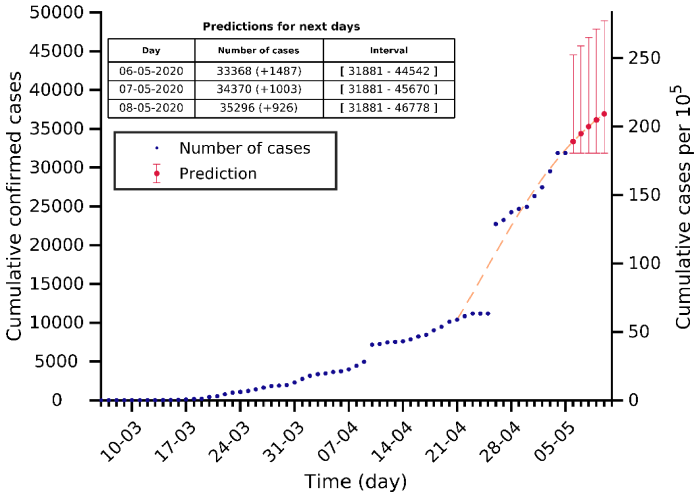


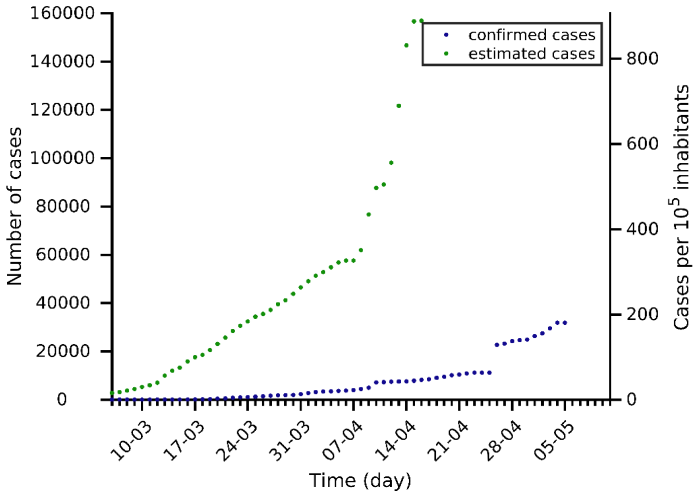


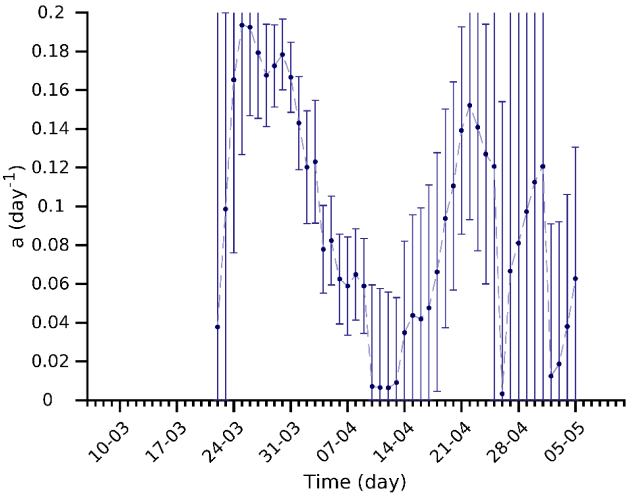


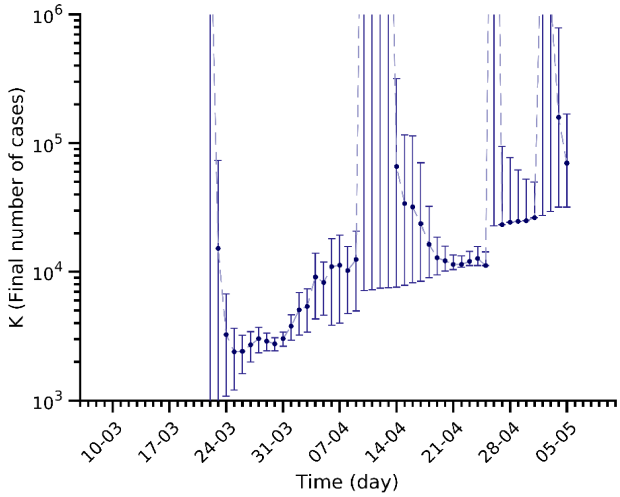


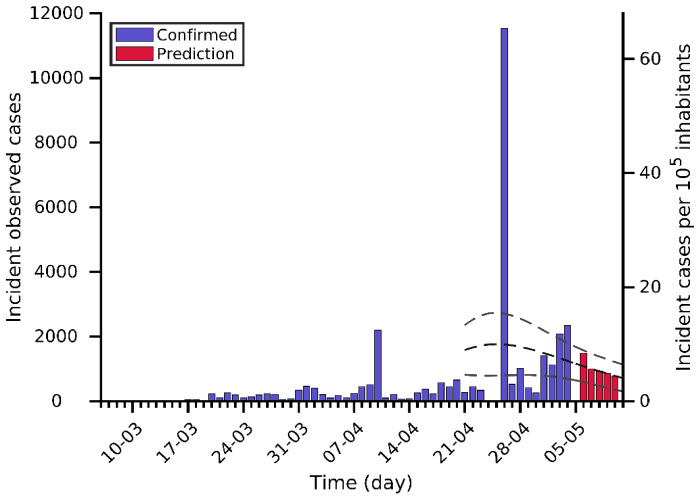
Ecuador 05-05-2020. Population: 17.6M. Current cumulated incidence: 181/10^5

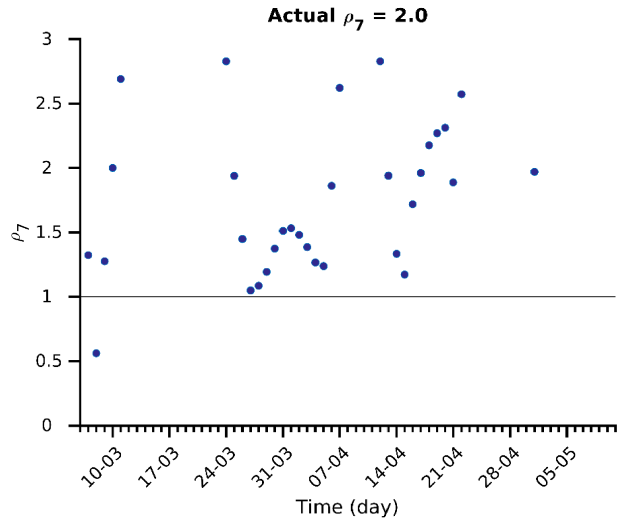


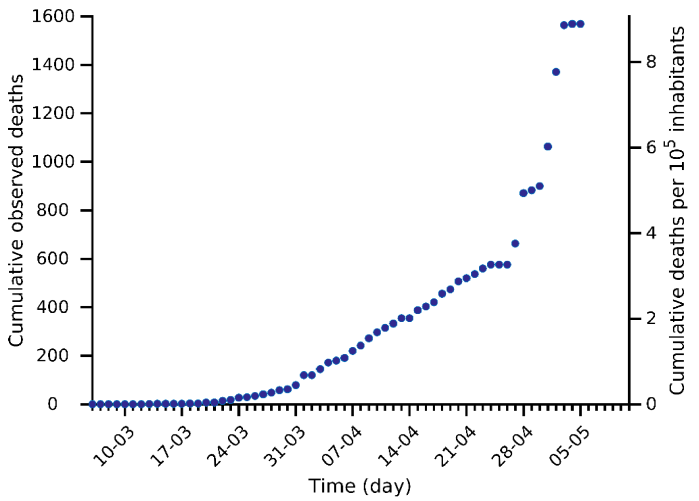


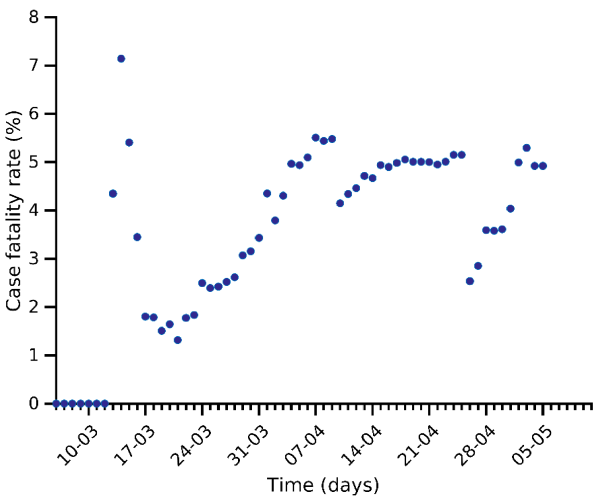




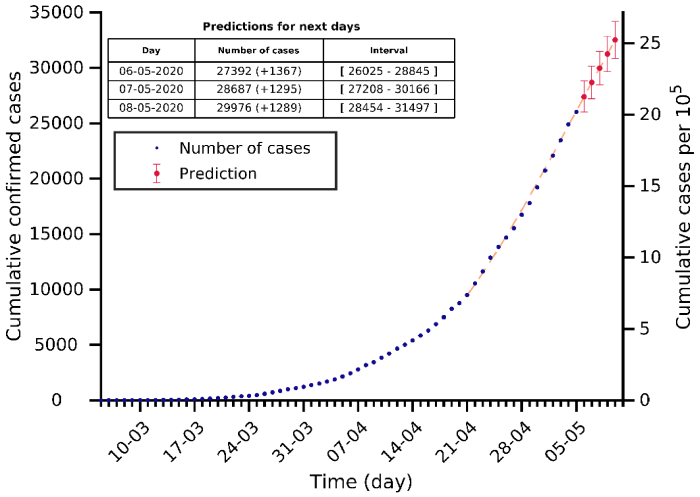


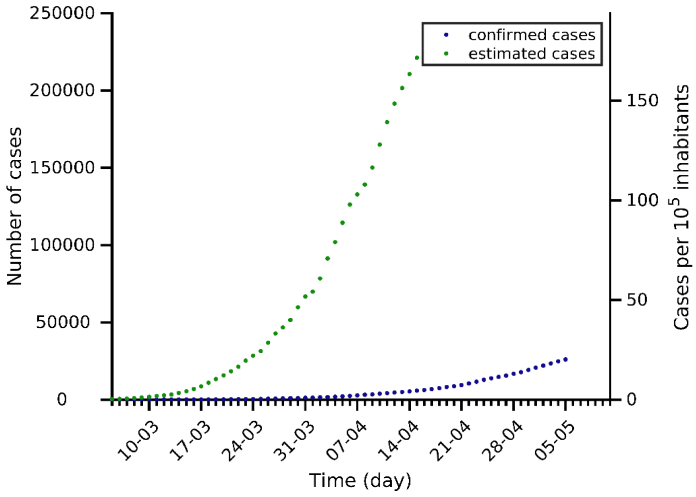


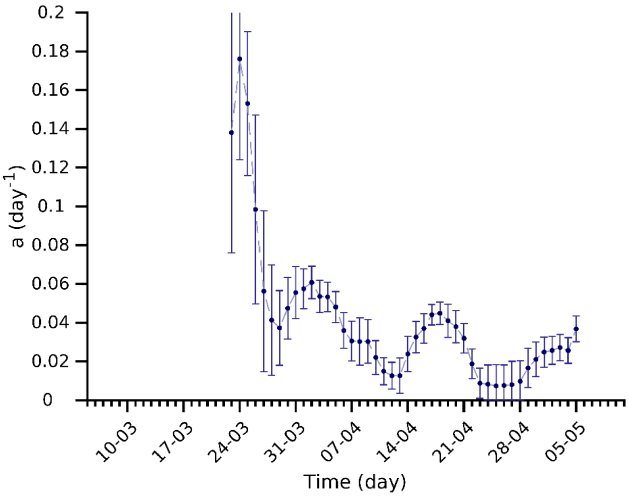


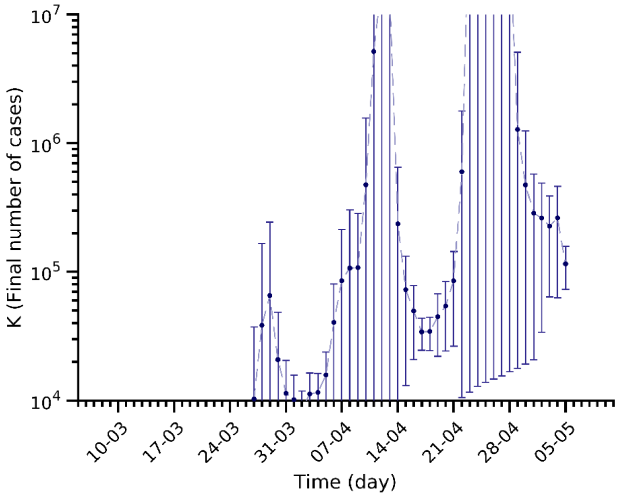


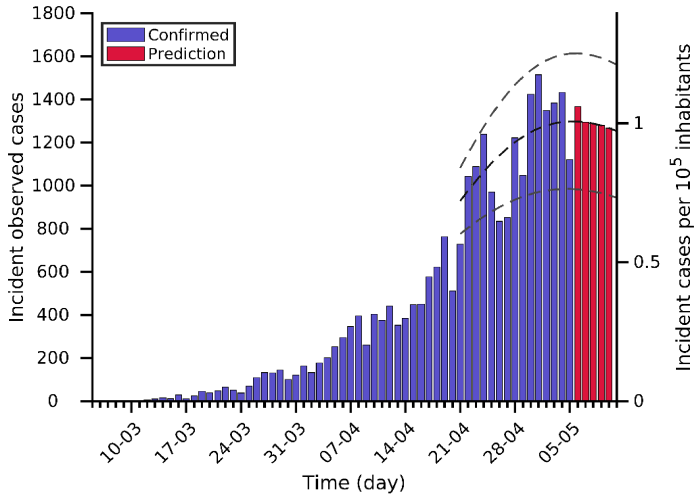
Mexico 05-05-2020. Population: 128.9M. Current cumulated incidence: $20/10^5$

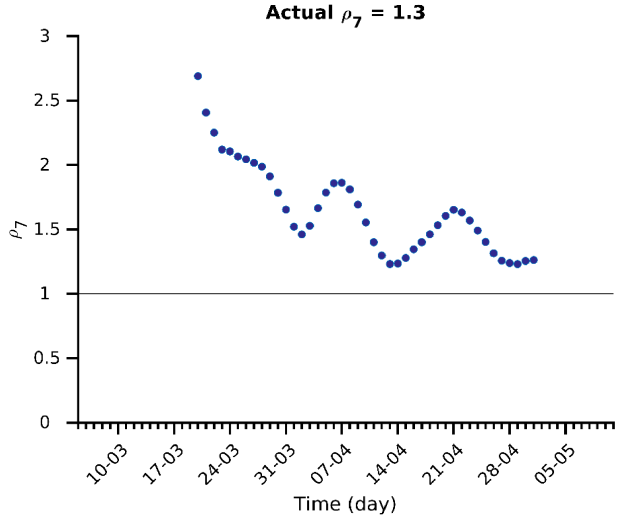


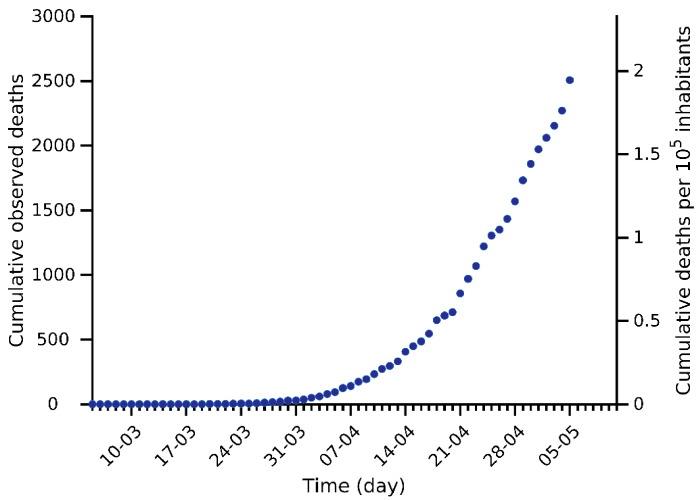


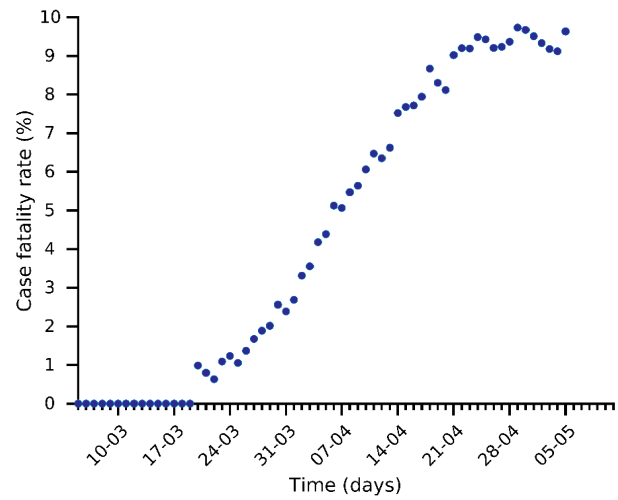




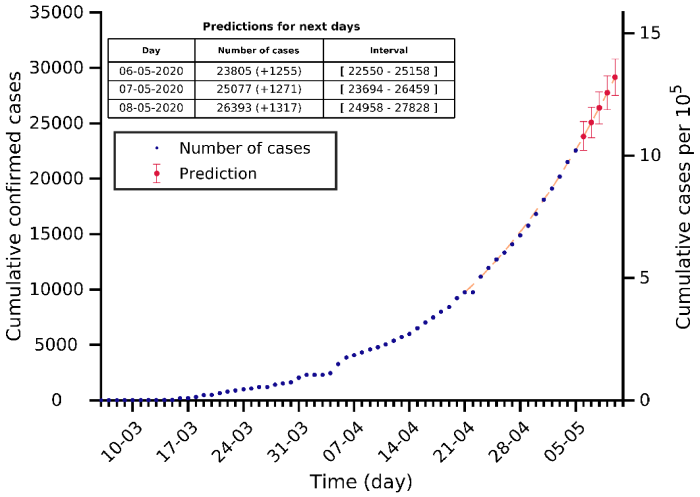


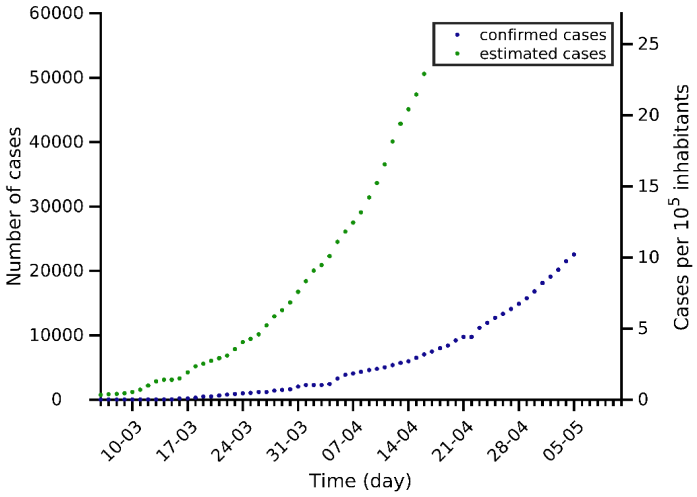


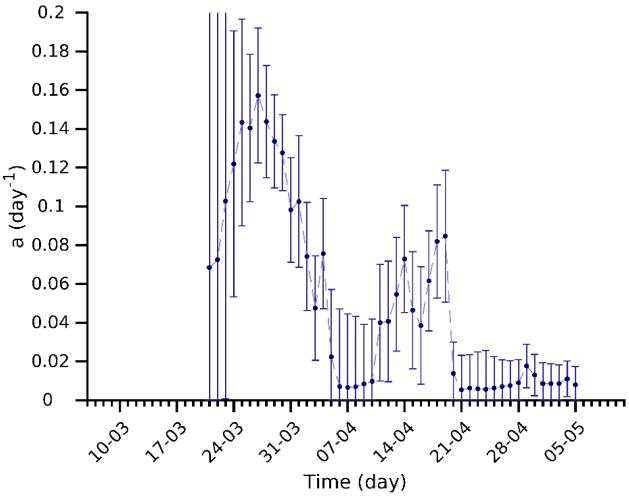


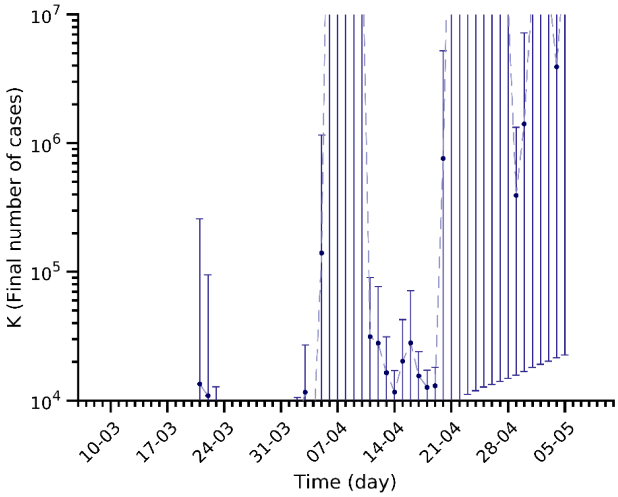


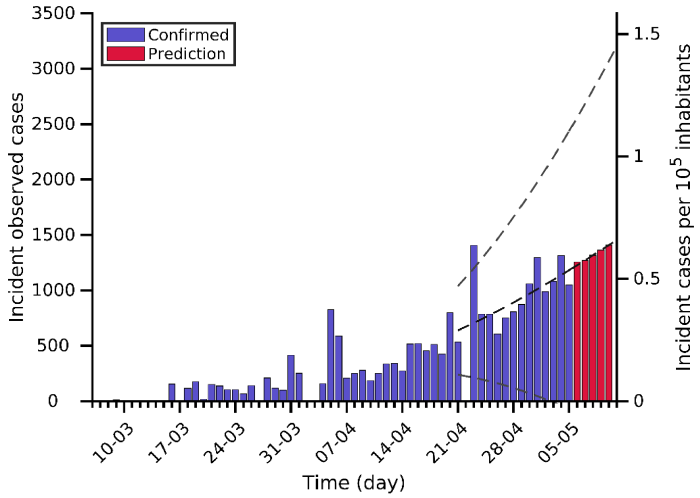
Pakistan 05-05-2020. Population: 220.9M. Current cumulated incidence: $10/10^5$

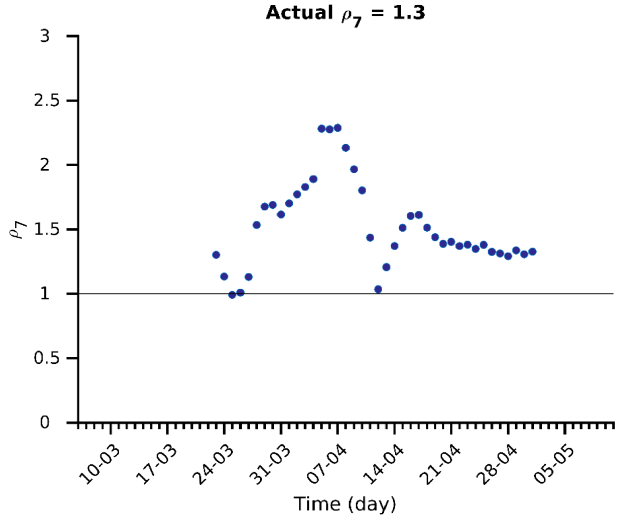


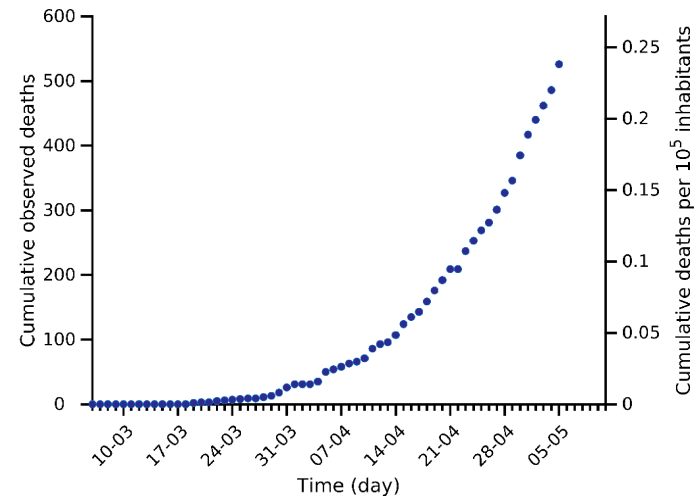


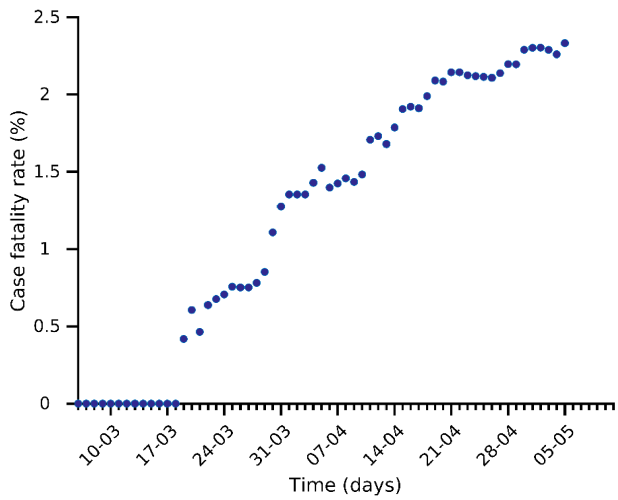




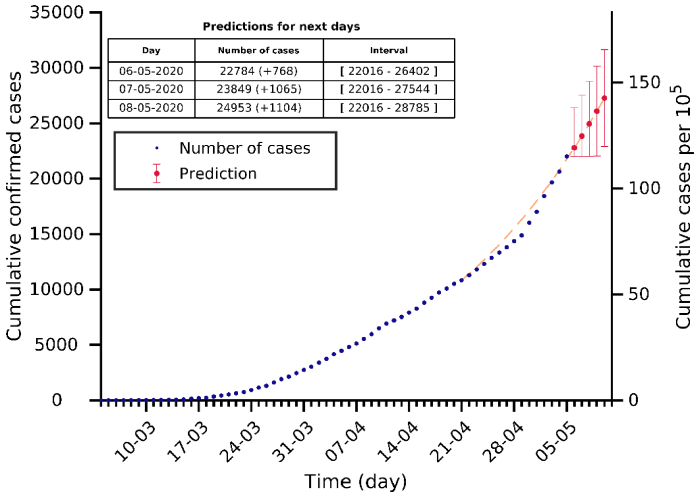


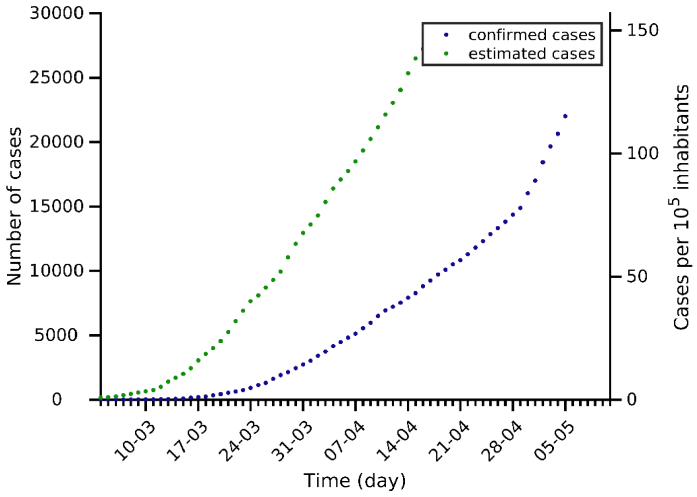


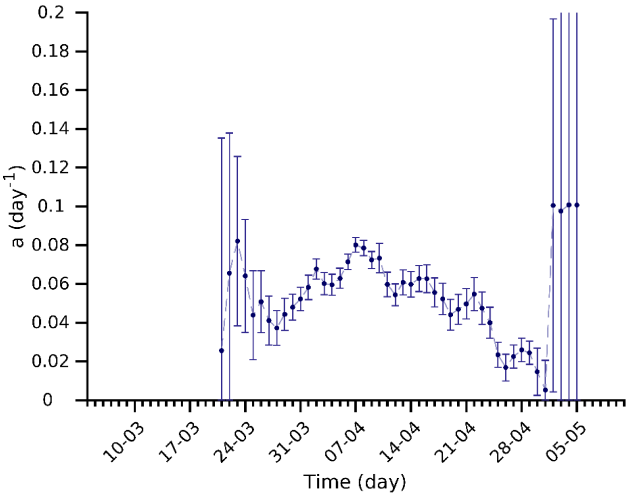


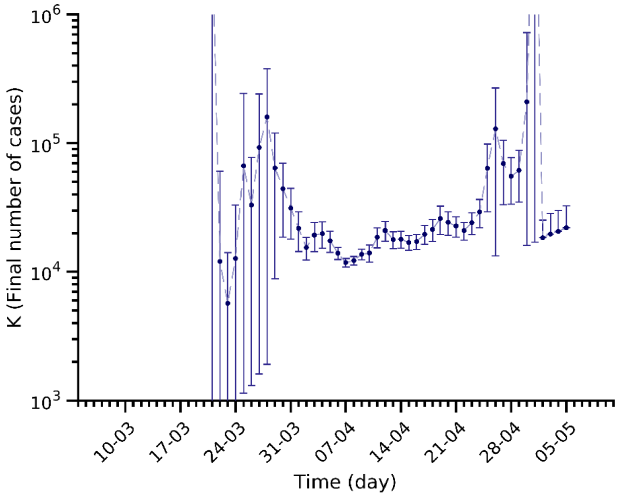


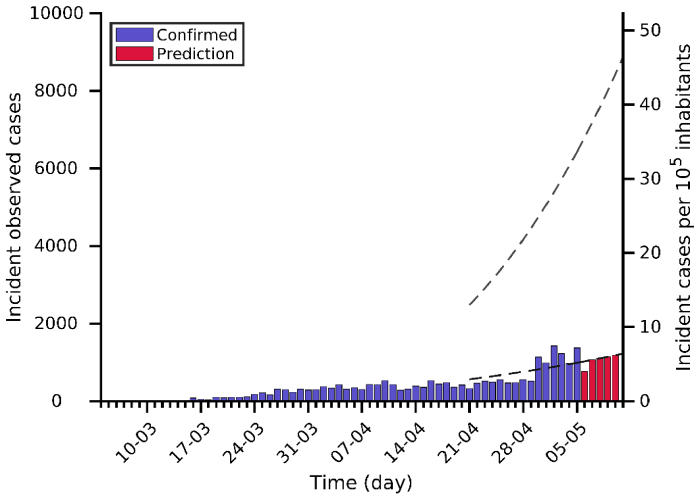
Chile 05-05-2020. Population: 19.1M. Current cumulated incidence: 115/10^5

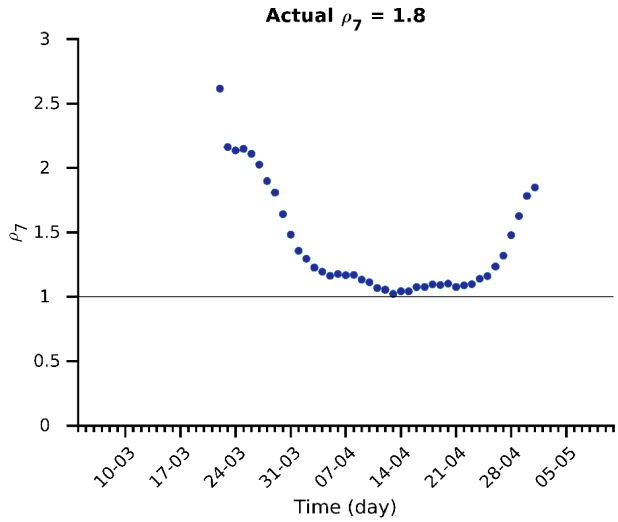


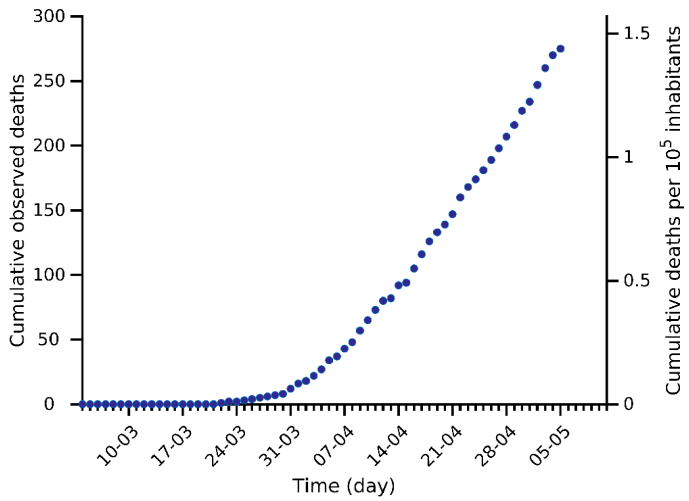


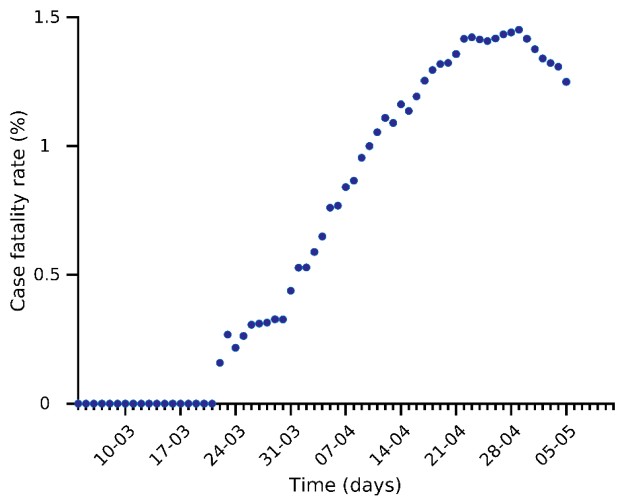




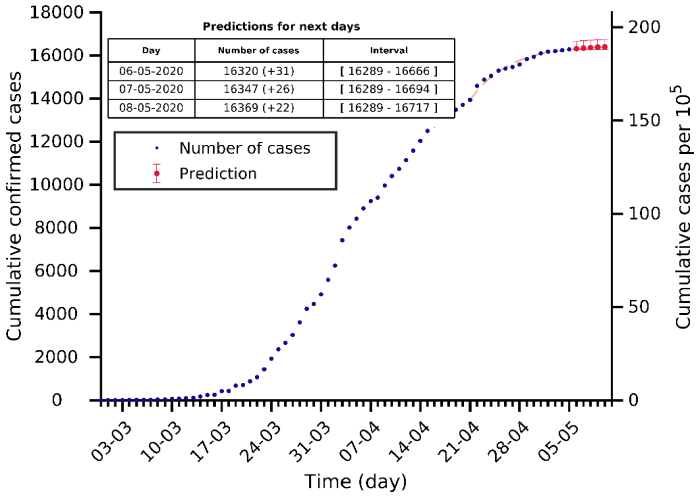


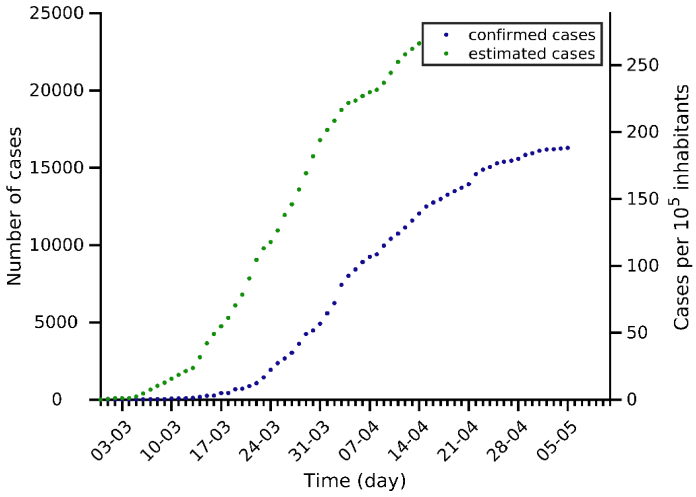


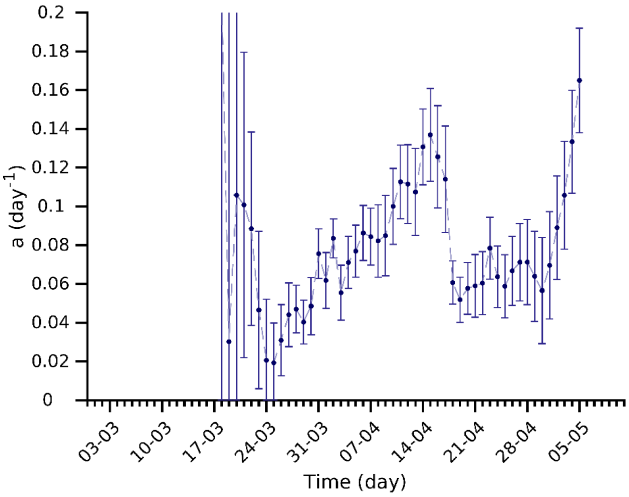


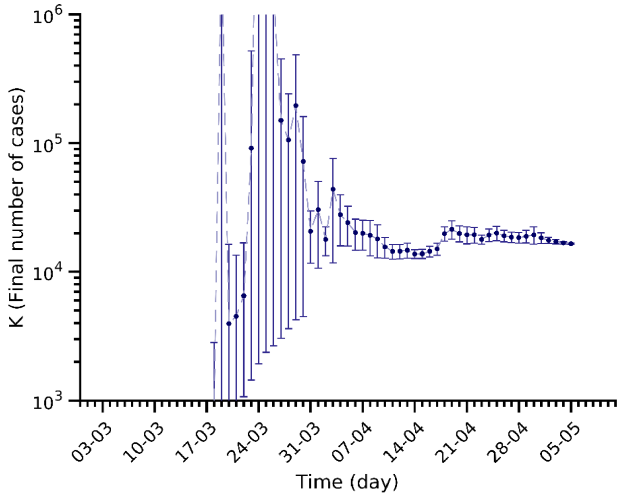


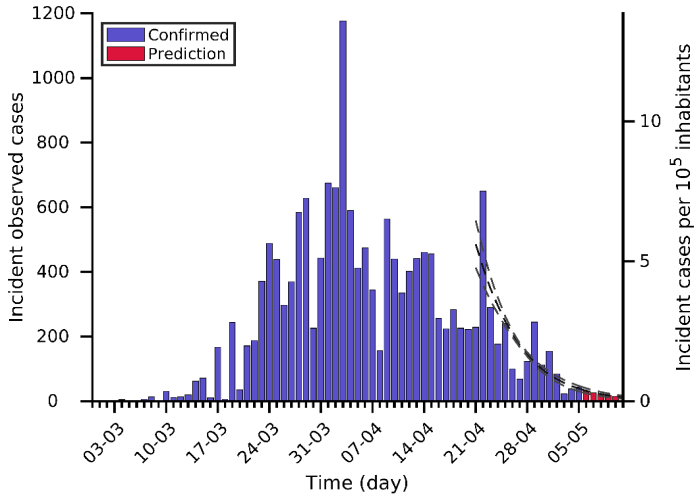
Israel 05-05-2020. Population: 8.7M. Current cumulated incidence: $188/10^5$

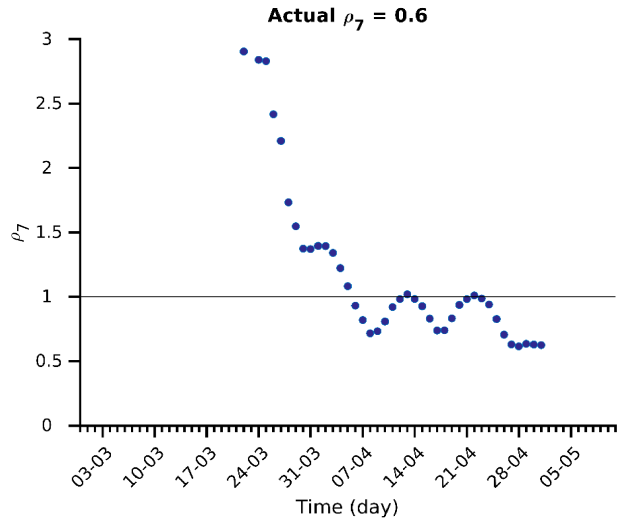


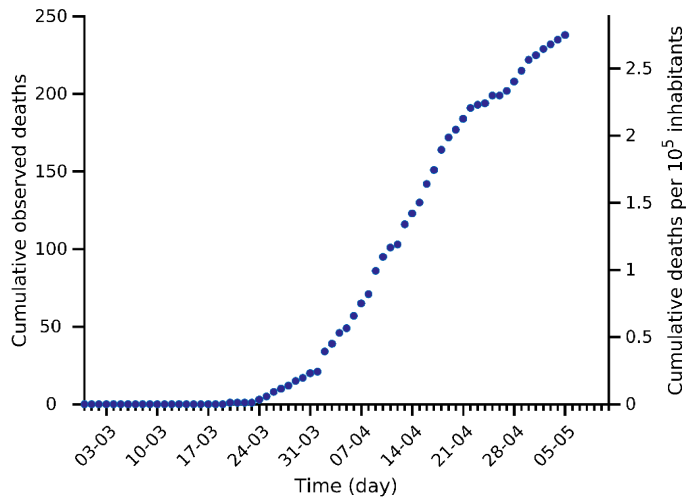


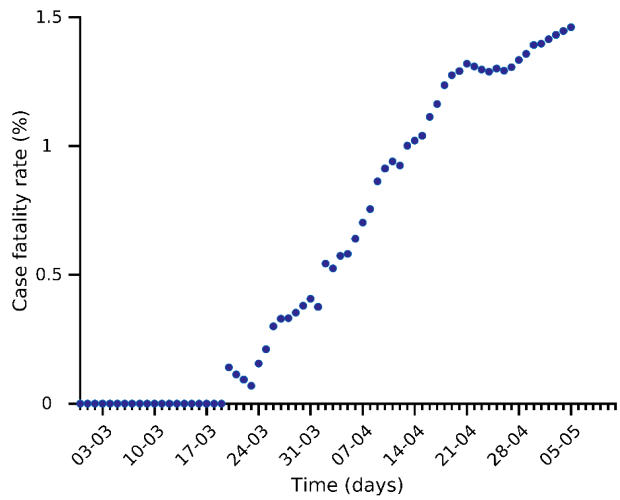




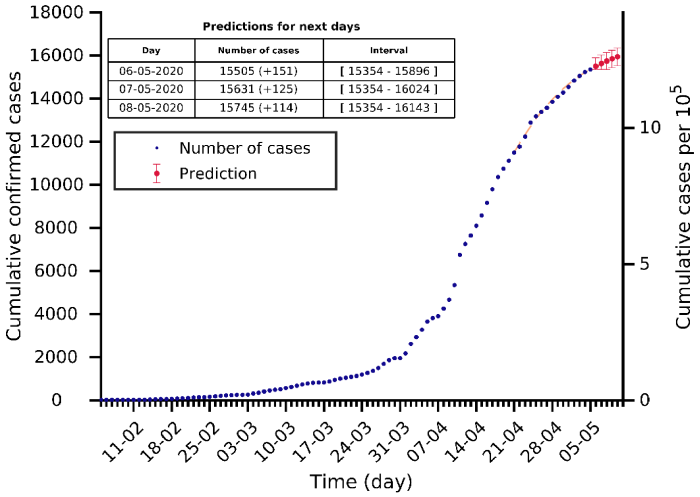


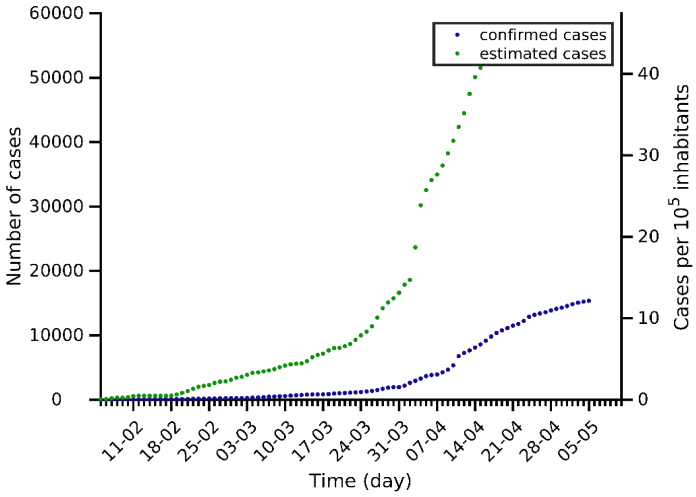


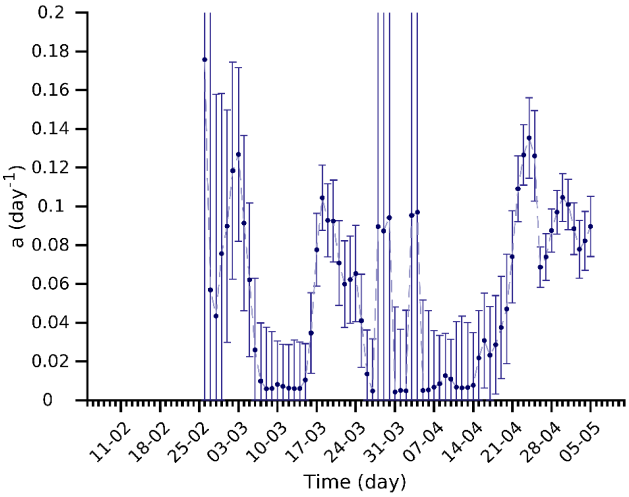


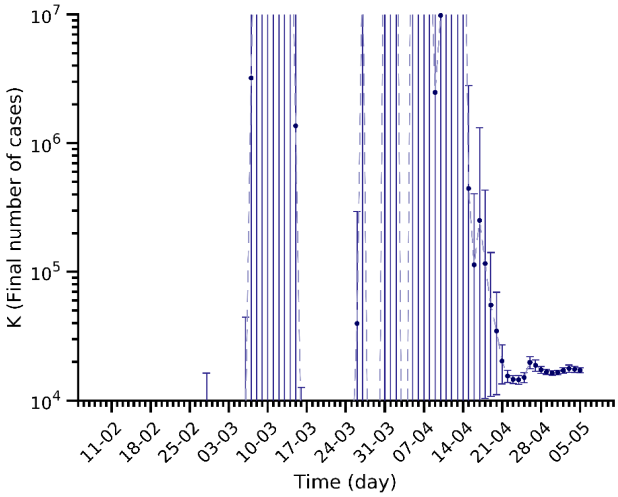


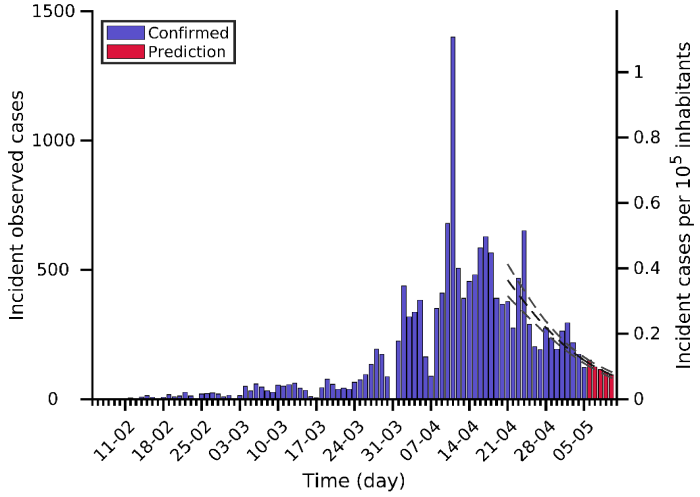
Japan 05-05-2020. Population: 126.5M. Current cumulated incidence: 12/10^5

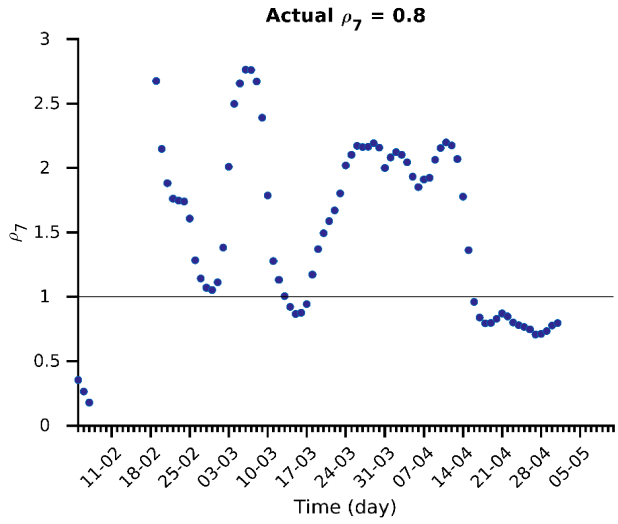


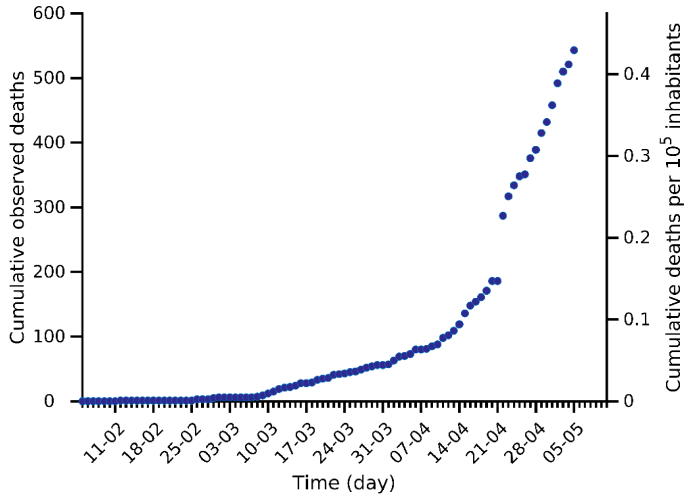


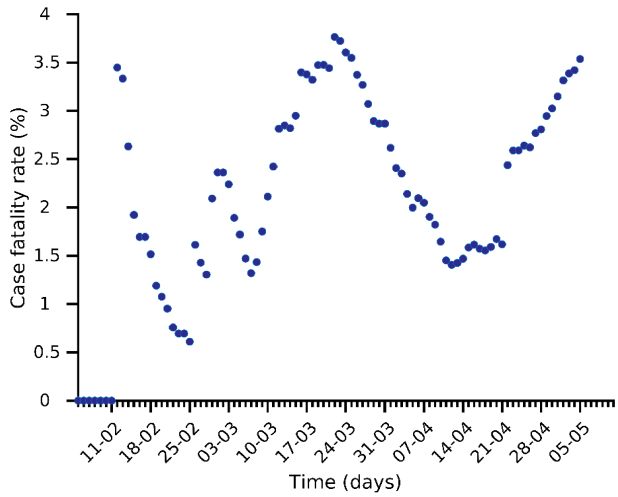




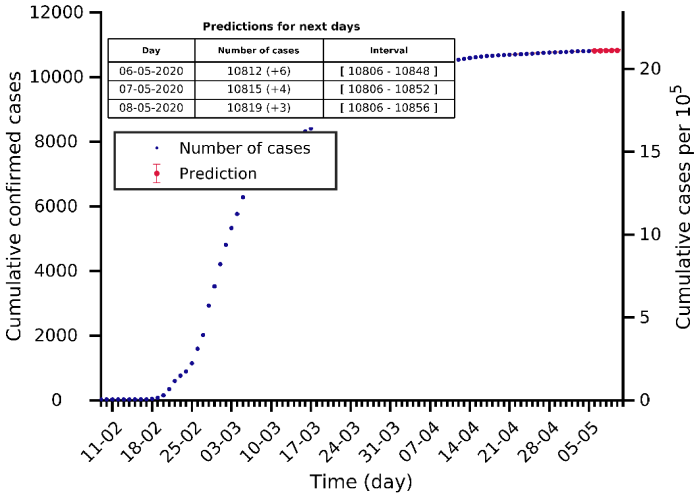


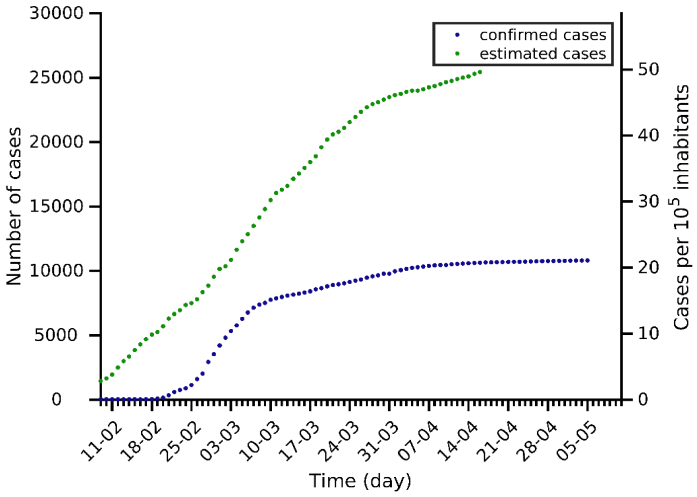


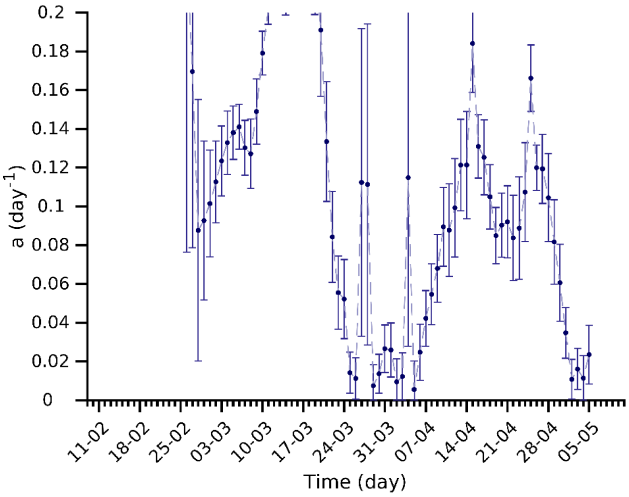


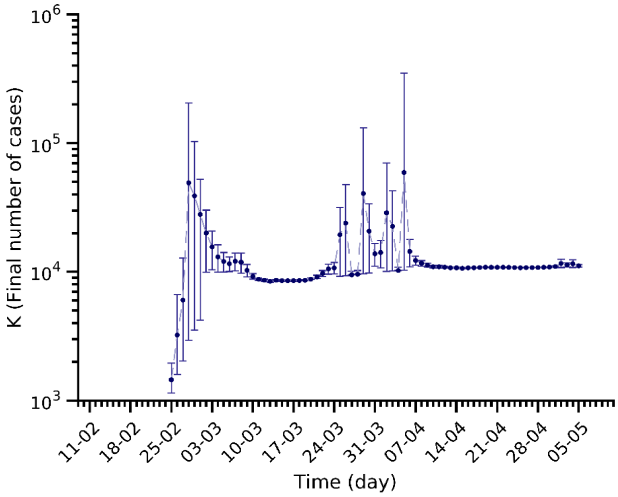


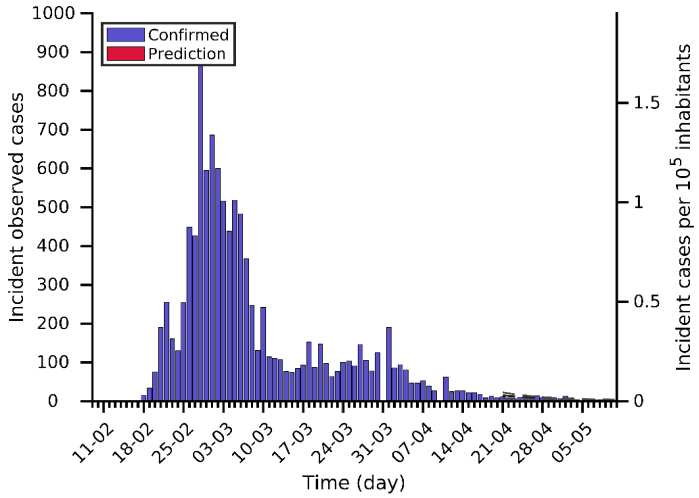
South Korea 05-05-2020. Population: 51.3M. Current cumulated incidence: $21/10^5$

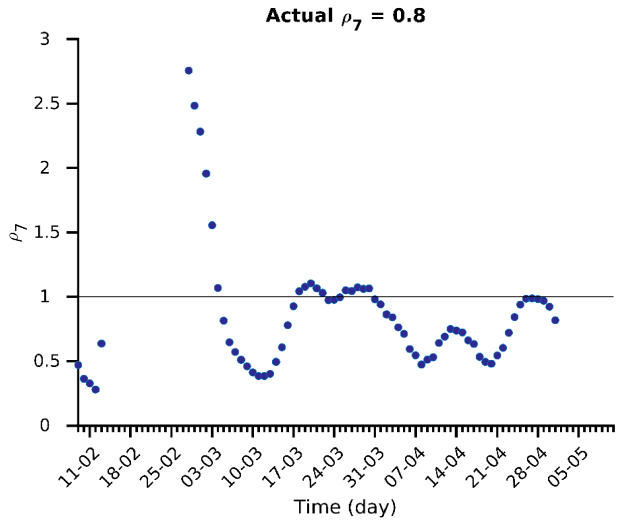


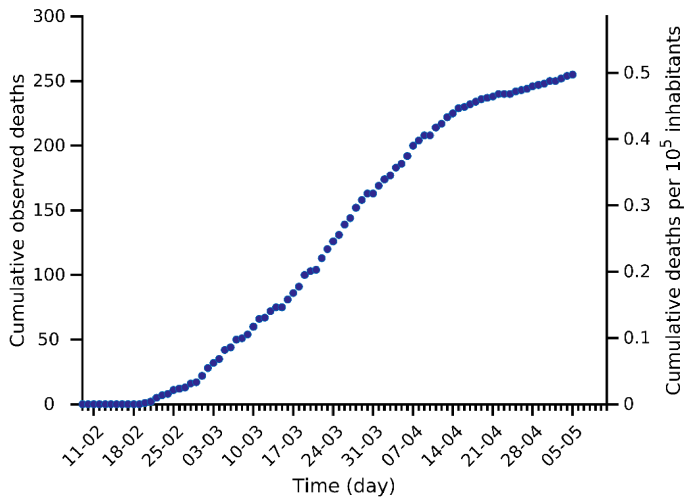


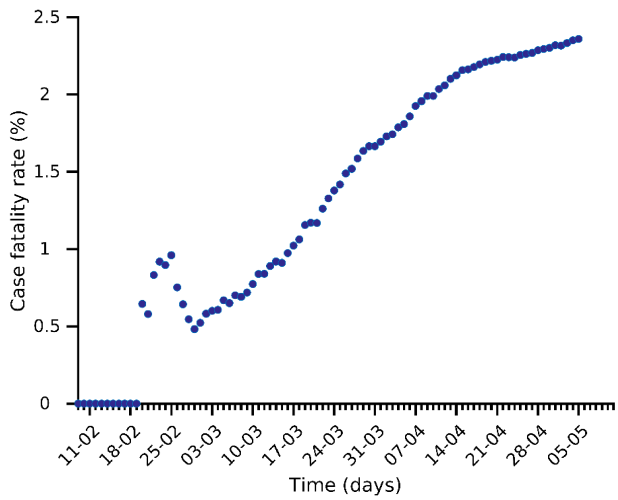




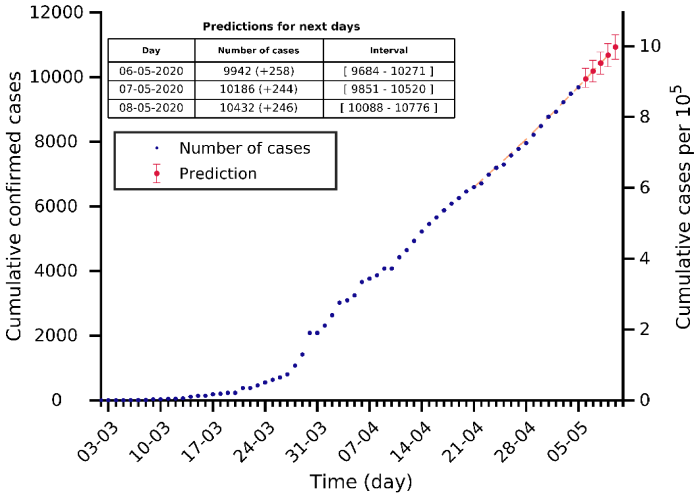


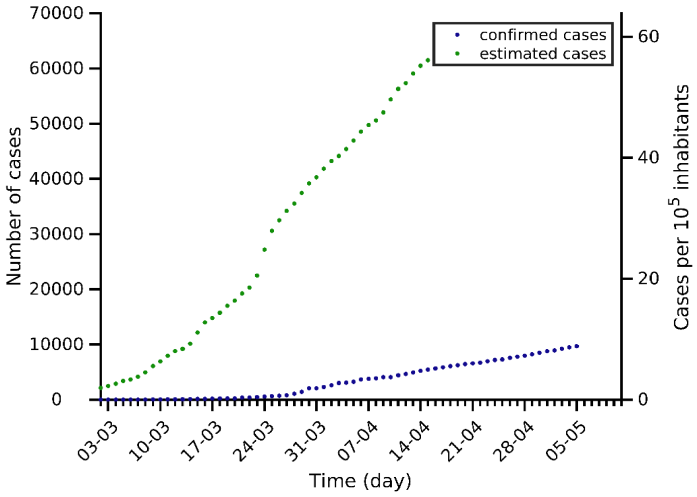


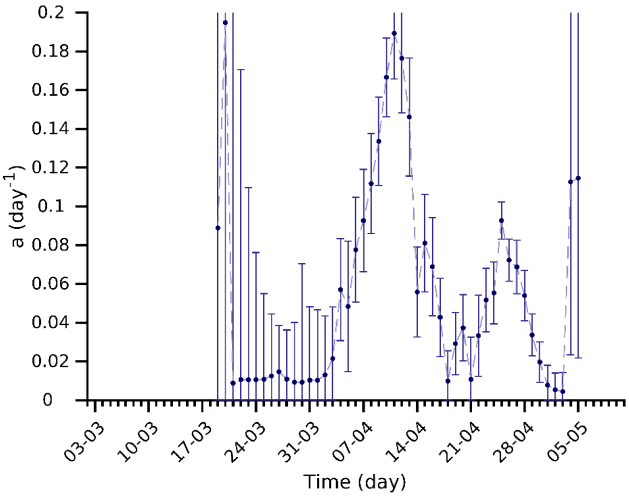


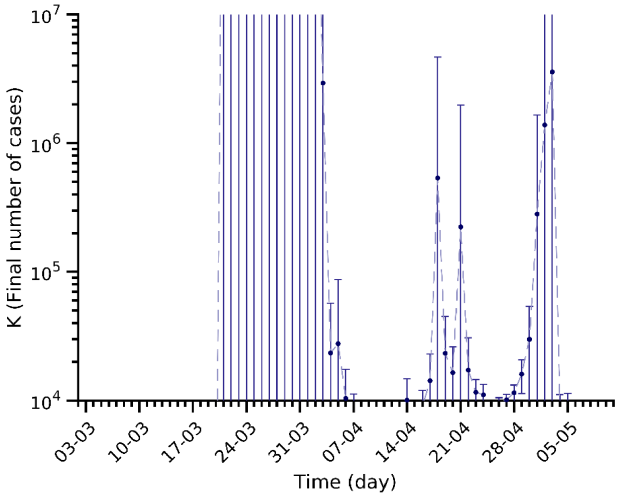


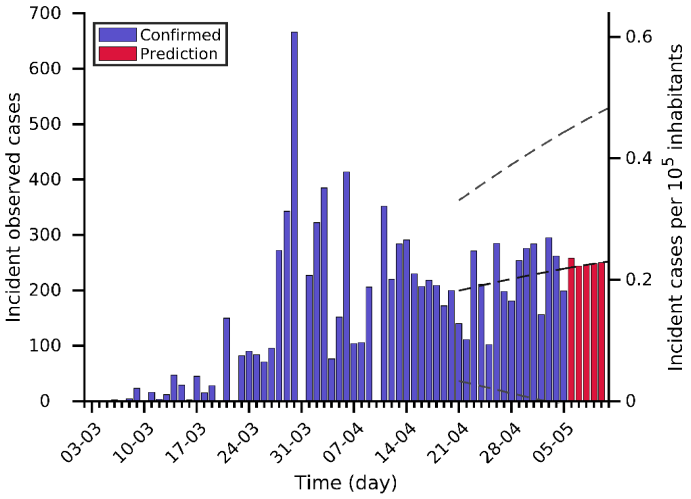
Philippines 05-05-2020. Population: 109.6M. Current cumulated incidence: $9/10^5$

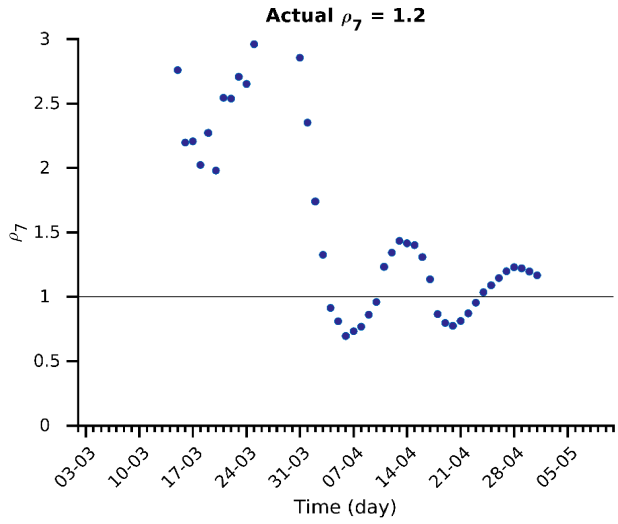


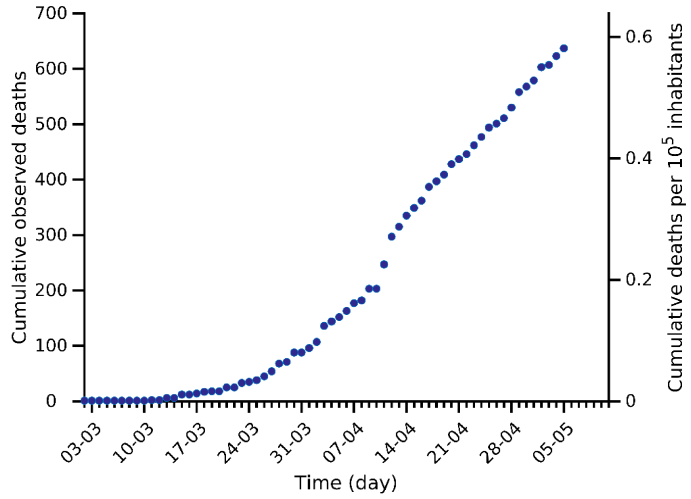


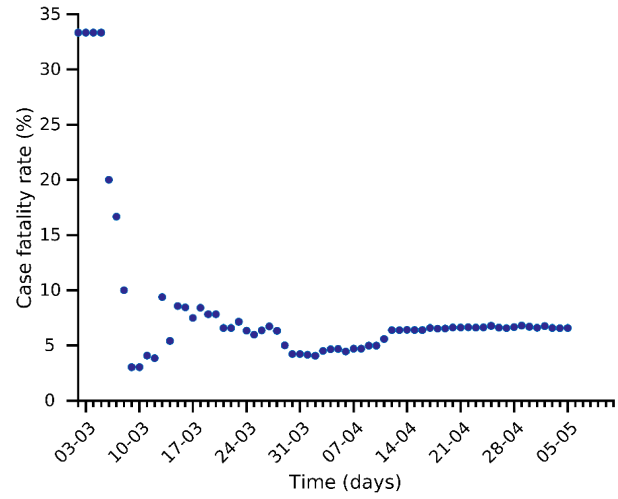




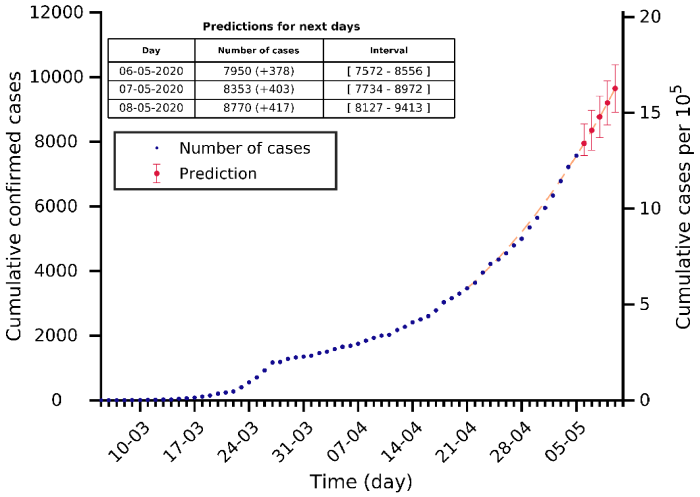


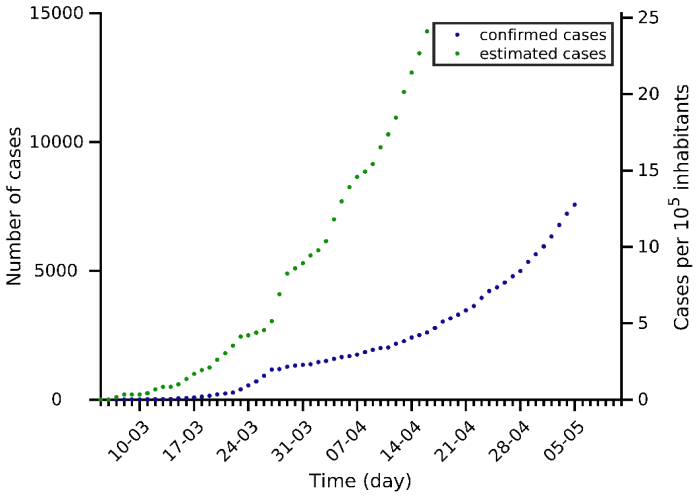


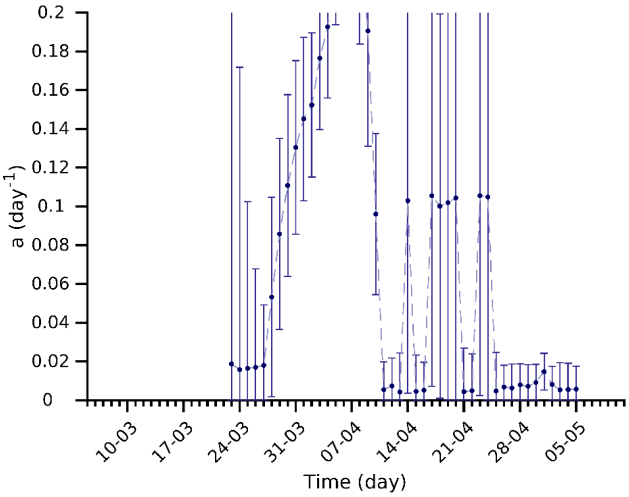


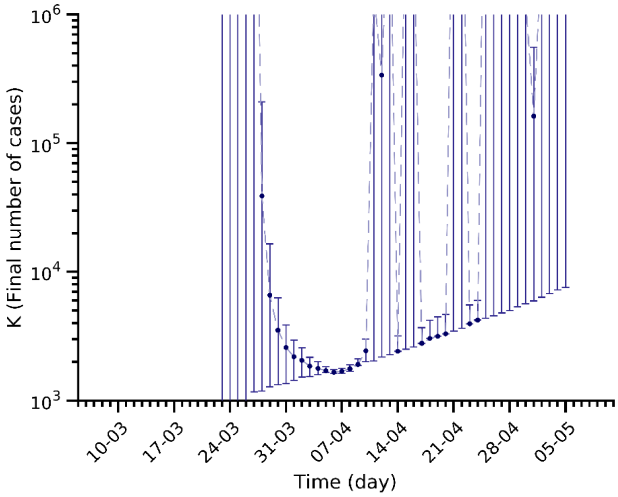


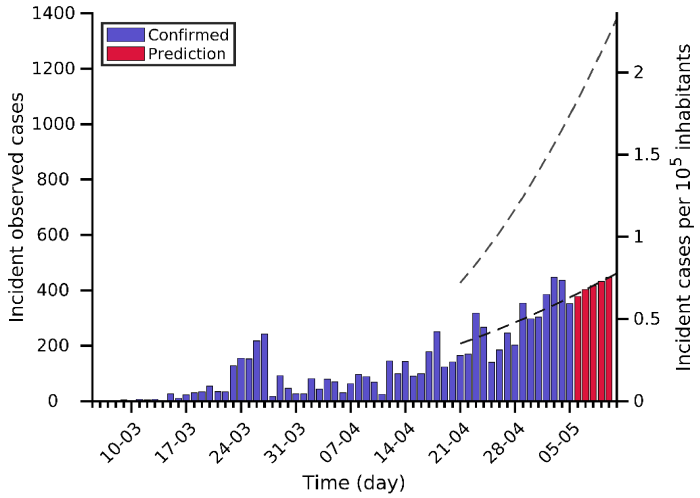
South Africa 05-05-2020. Population: 59.3M. Current cumulated incidence: 13/10^5

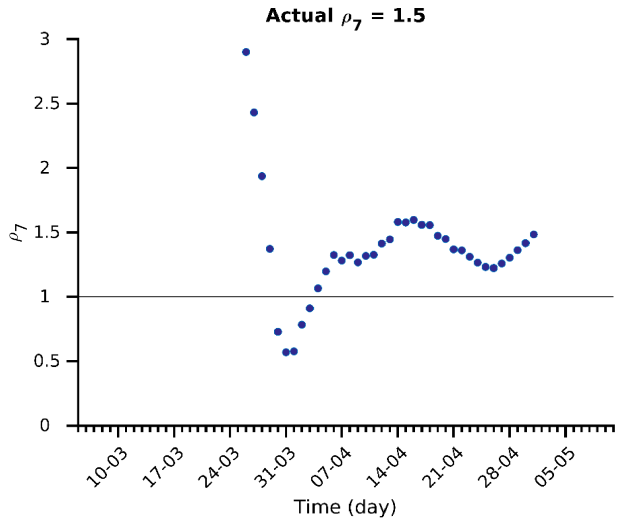


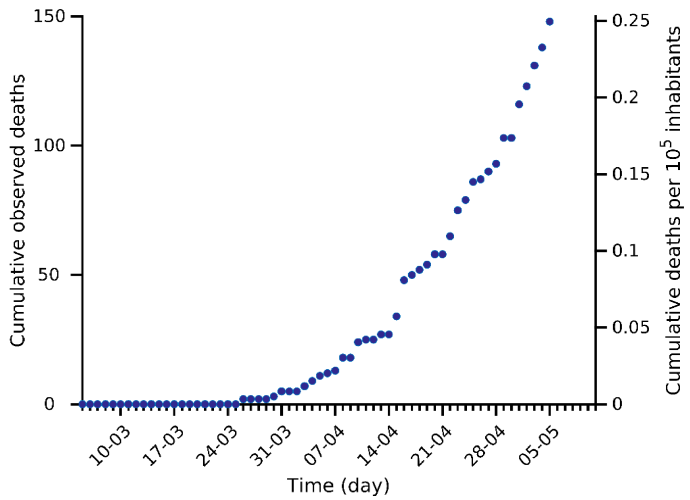


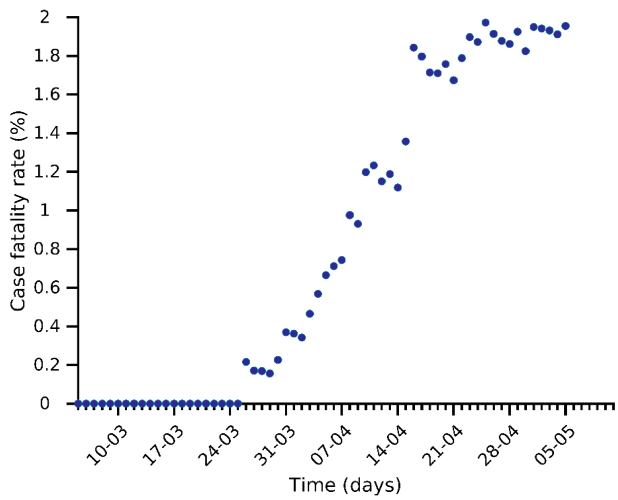




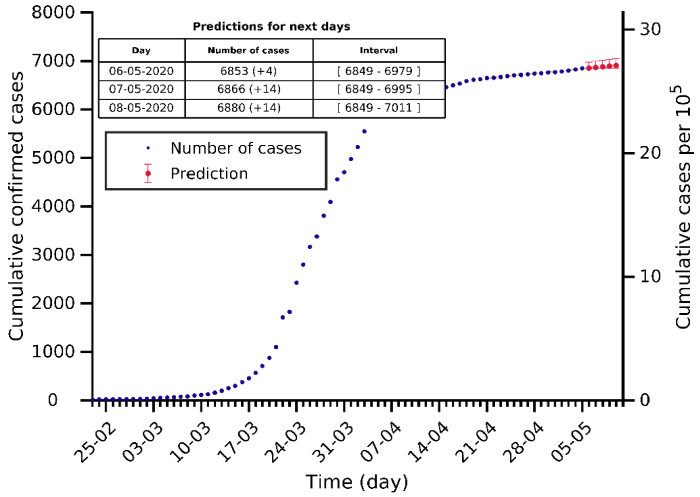


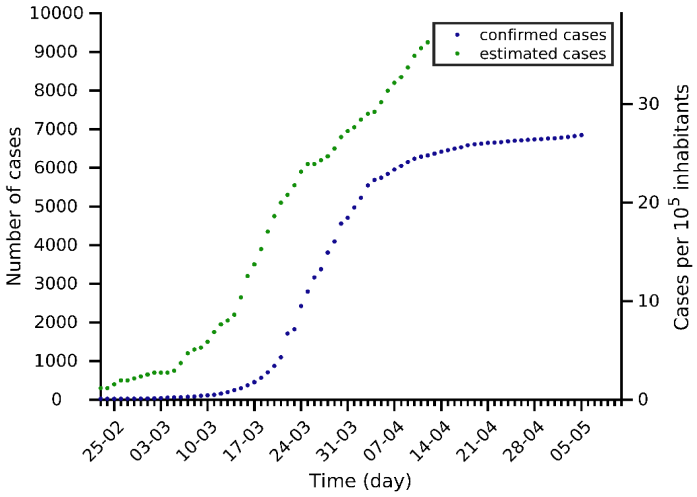


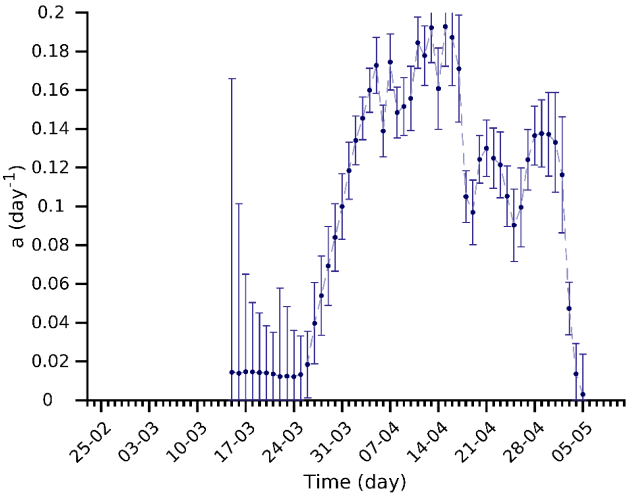


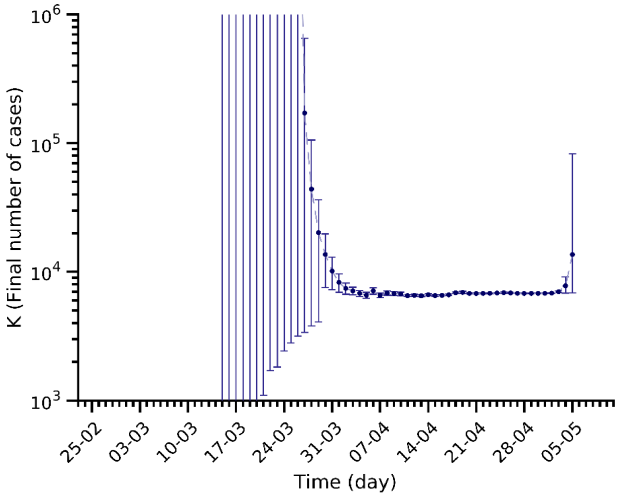


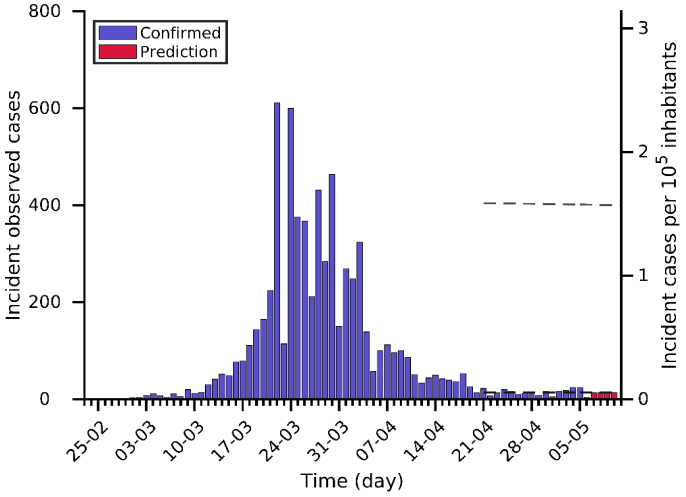
Australia 05-05-2020. Population: 25.5M. Current cumulated incidence: 27/10⁵

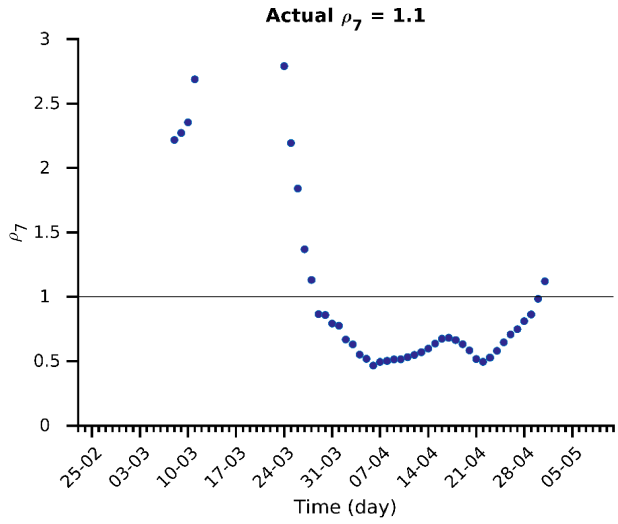


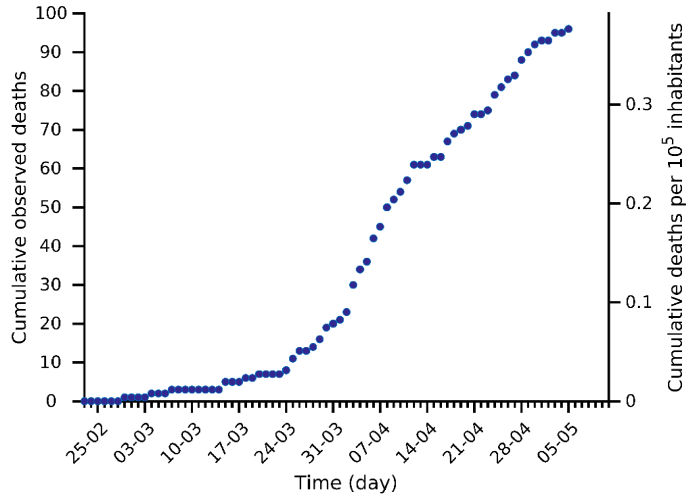


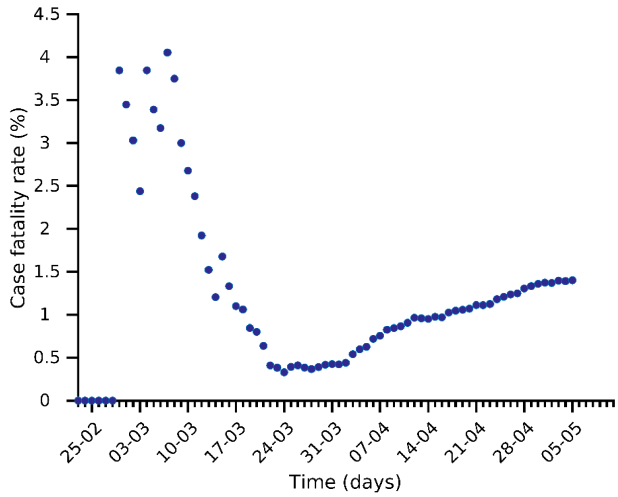




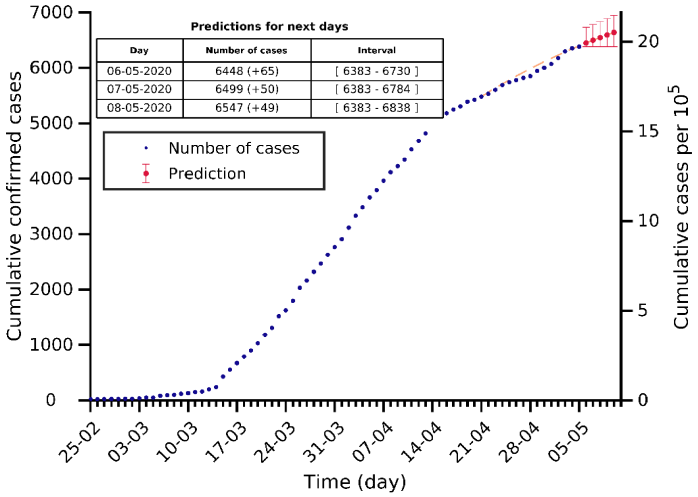


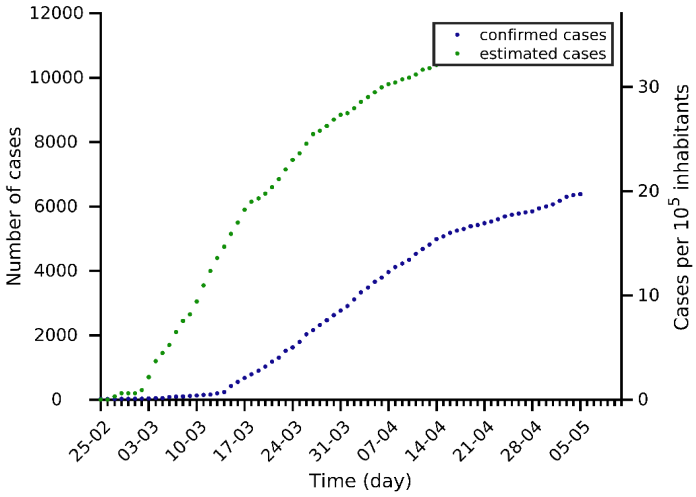


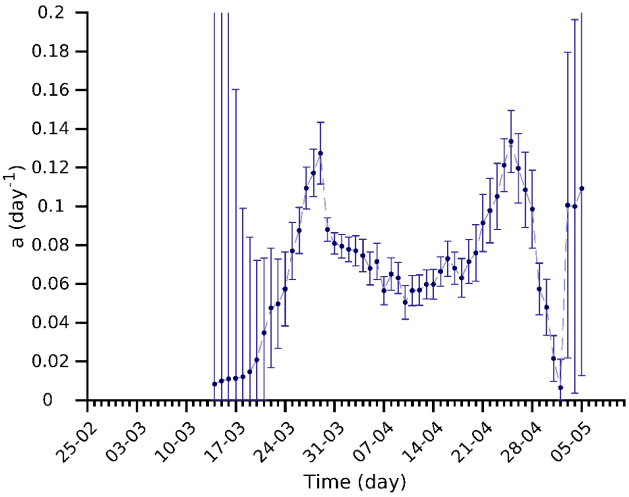


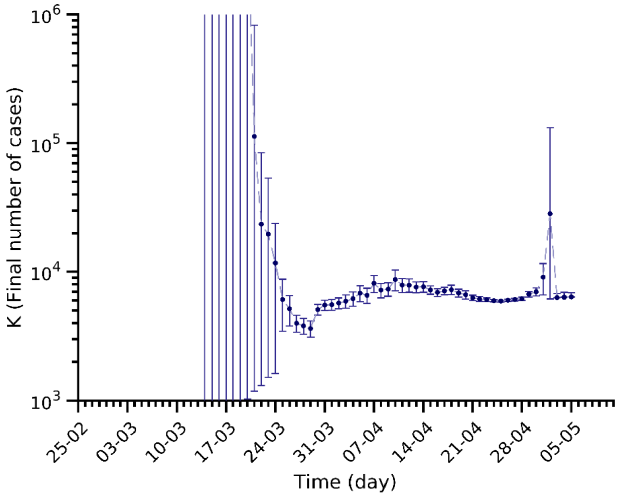


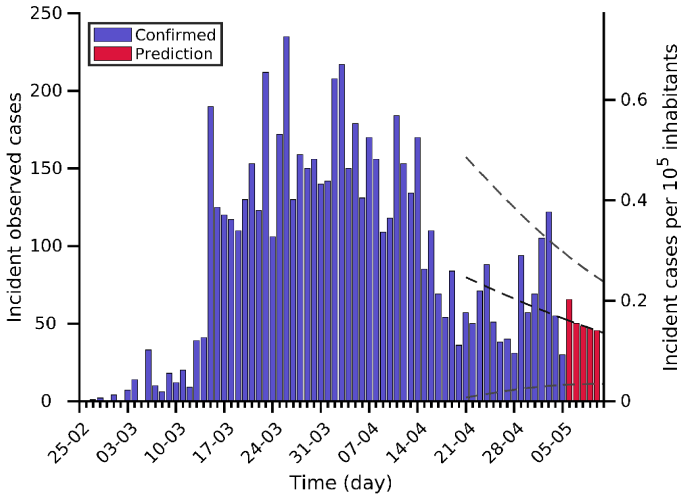
Malaysia 05-05-2020. Population: 32.4M. Current cumulated incidence: $20/10^5$

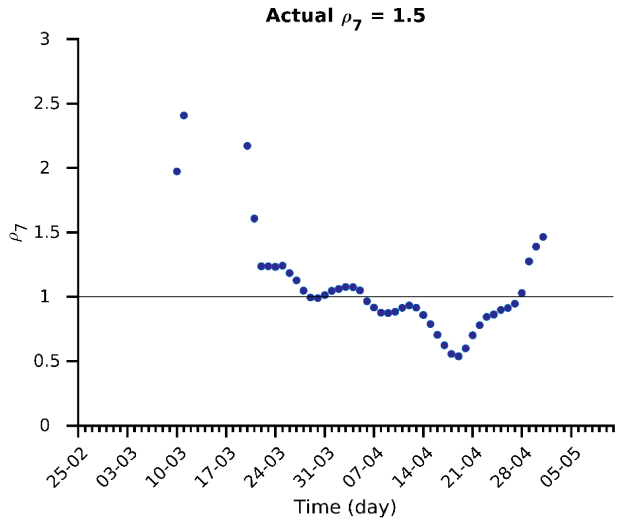


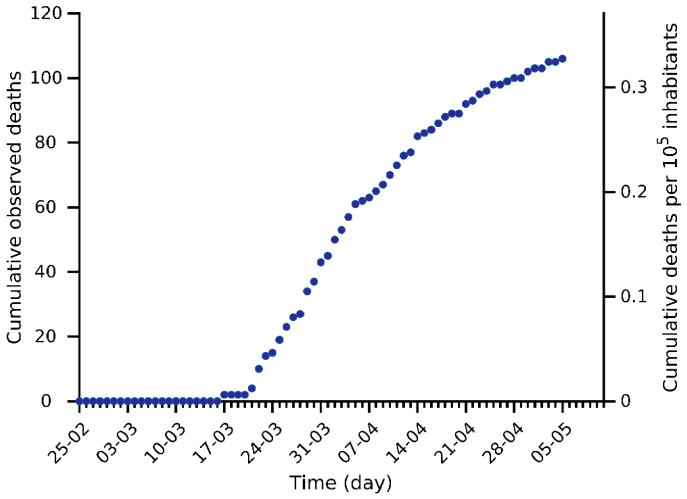


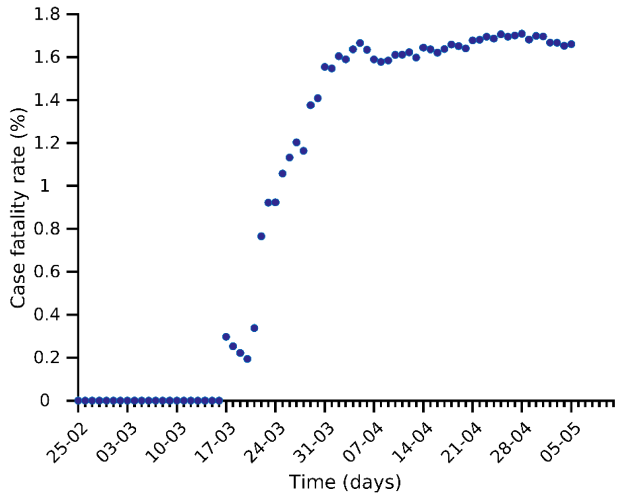








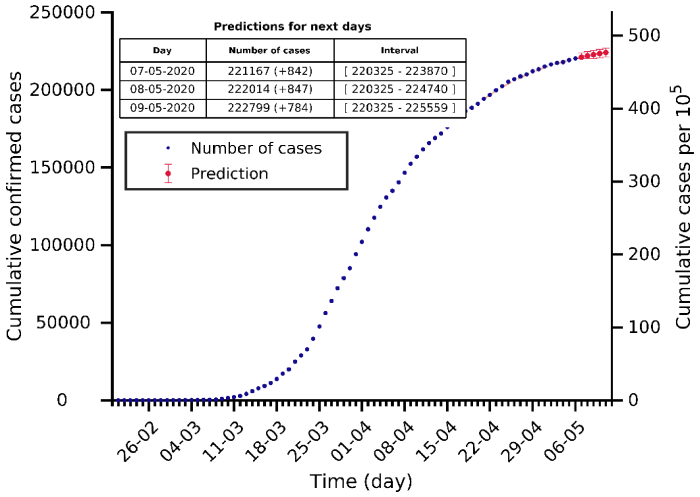


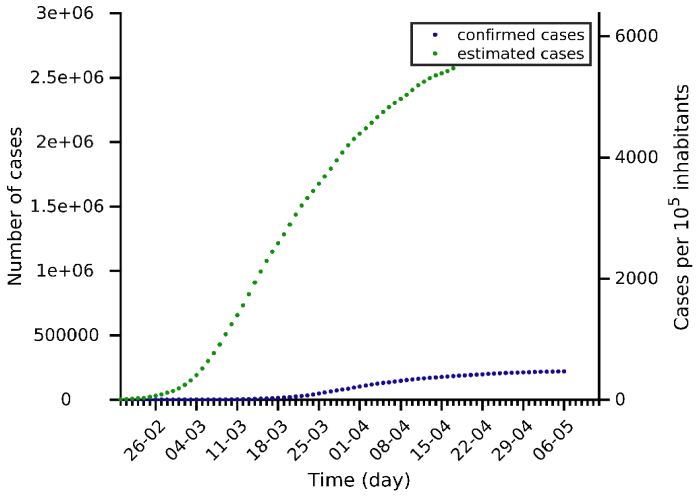


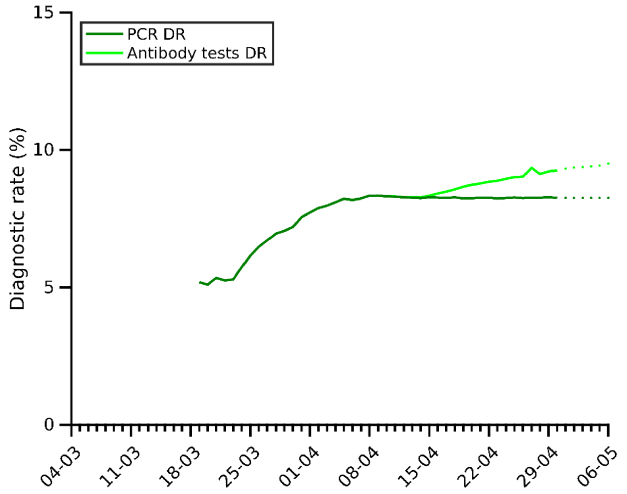
(3) Analysis and prediction of COVID-19 for Spain and its autonomous communities

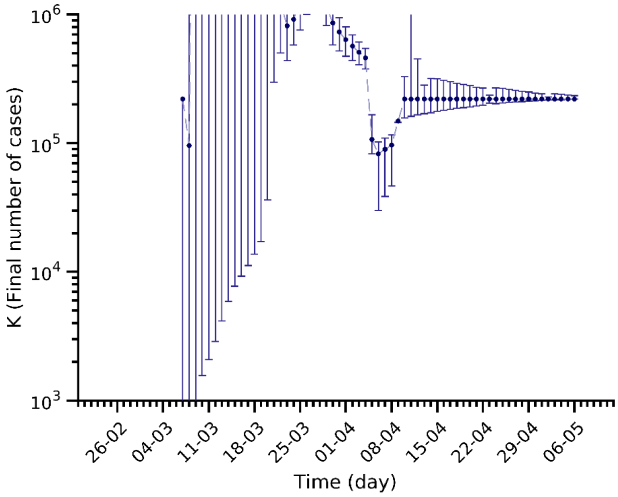
Data obtained from https://github.com/datadista/datasets/tree/master/COVID%2019 and https://covid19.isciii.es/

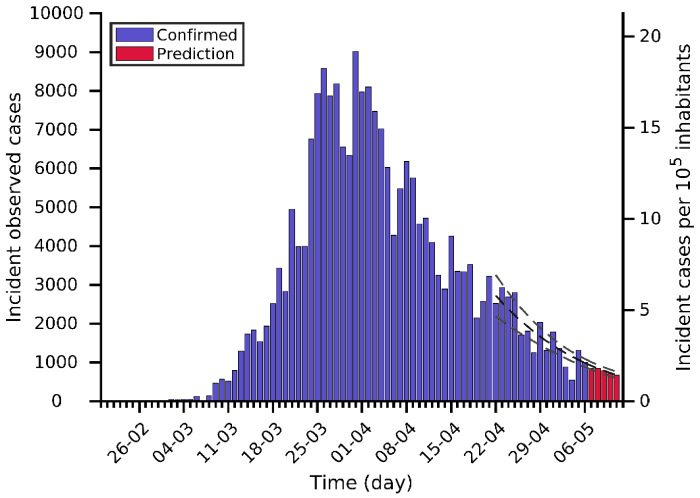
Spain 06-05-2020. Population: 47.0M. Current cumulated incidence: 469/10⁵

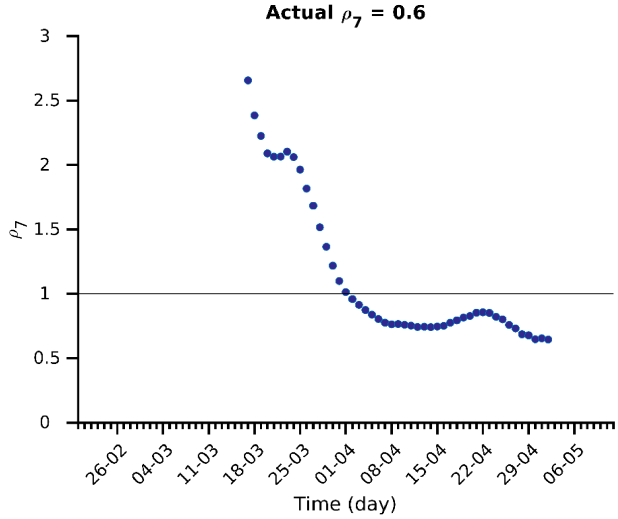


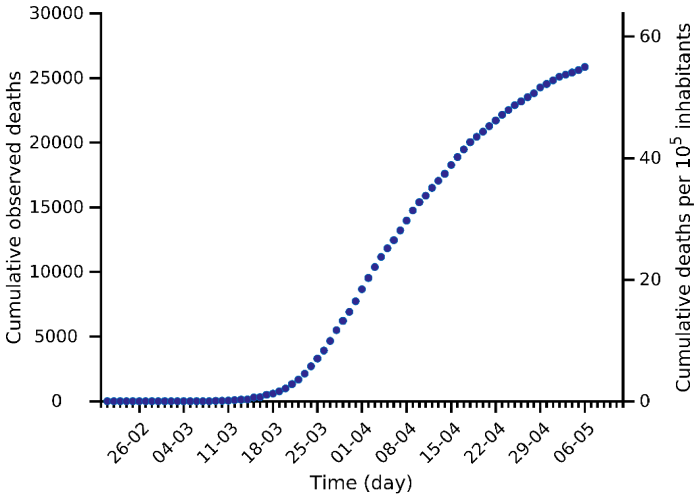


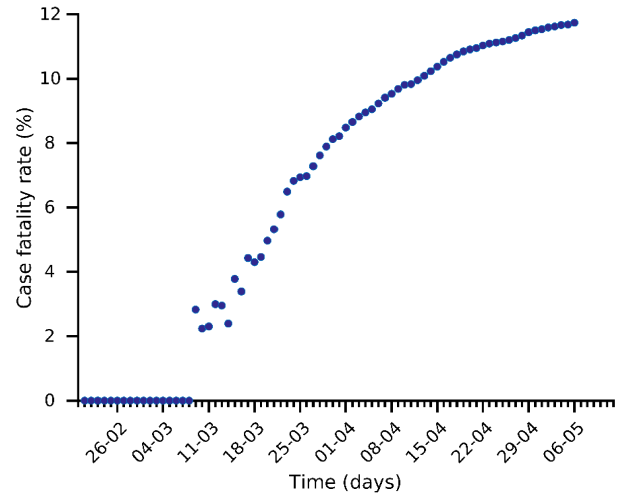




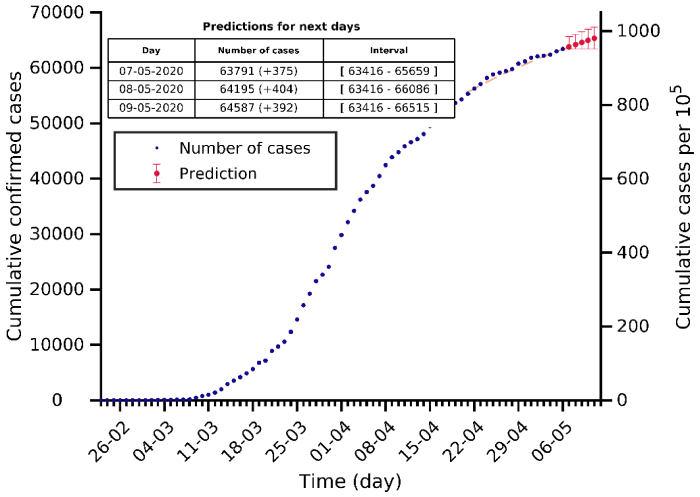


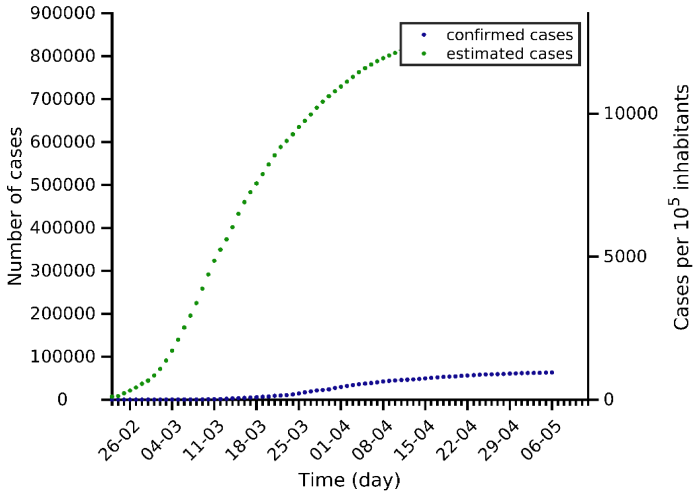


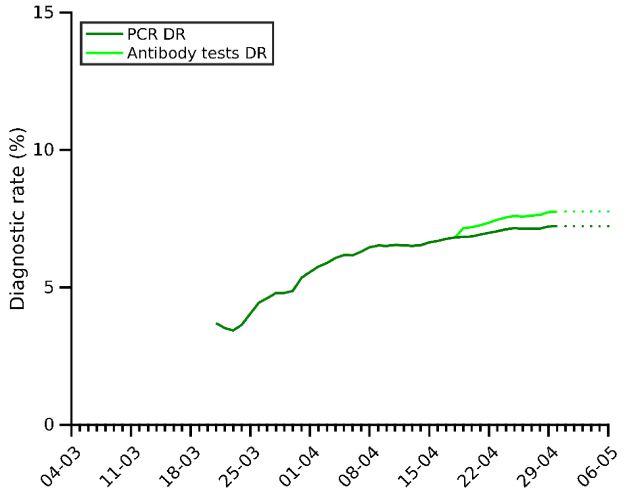


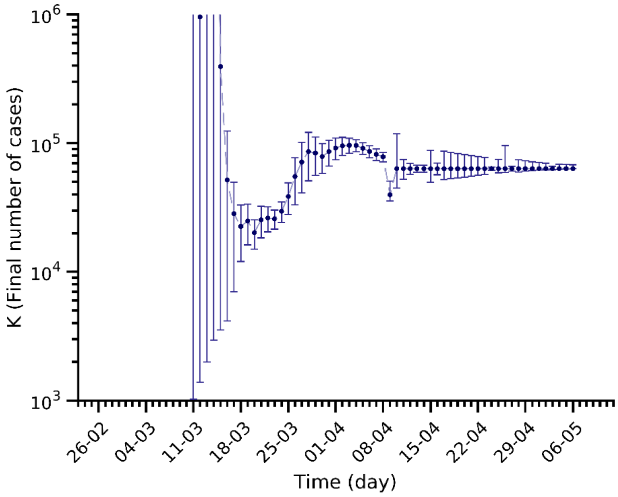


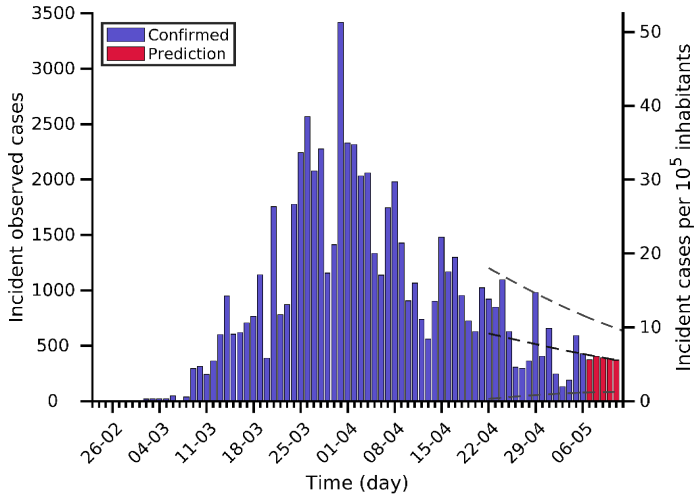
Madrid 06-05-2020. Population: 6.7M. Current cumulated incidence: 952/10^5

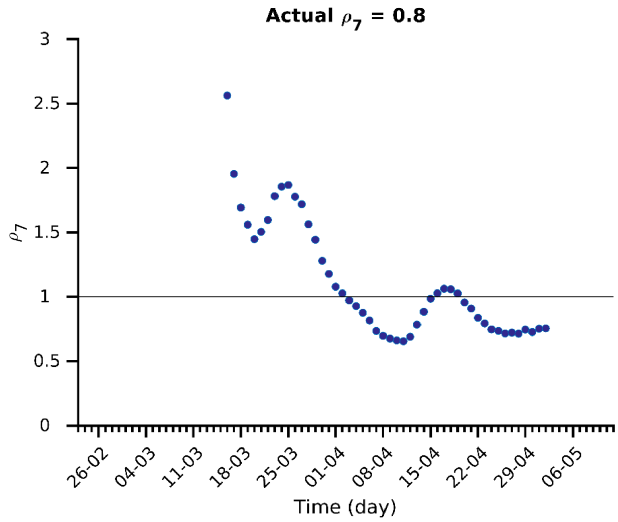


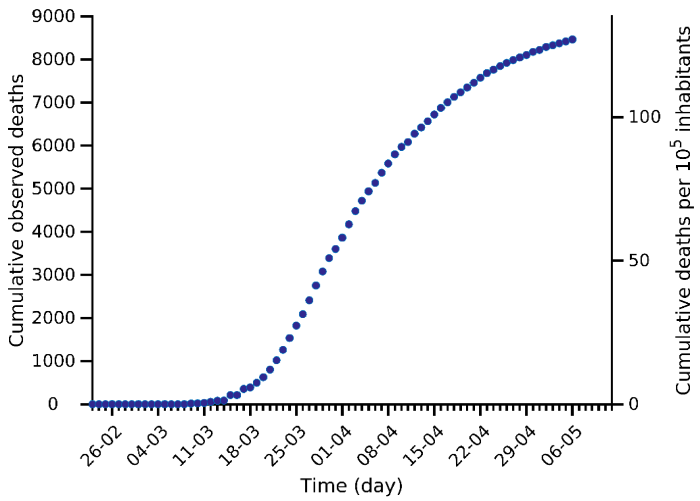


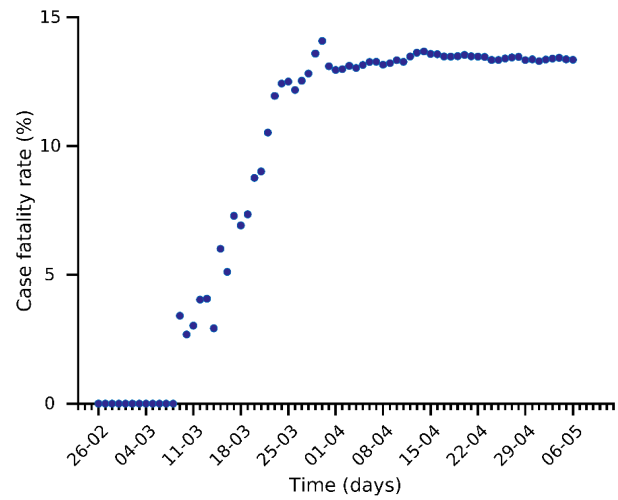




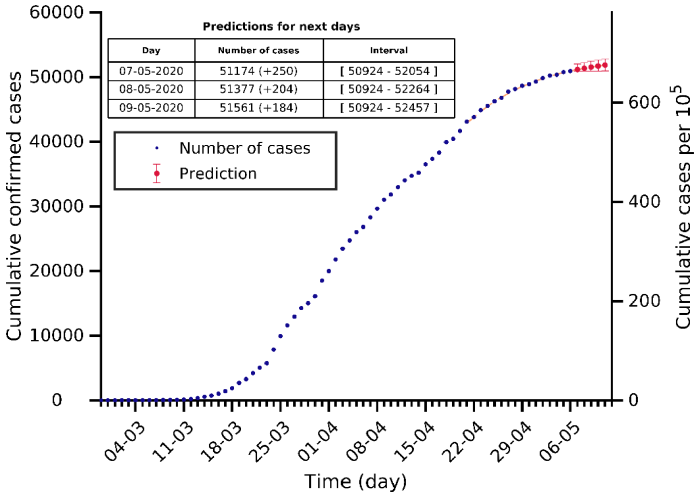


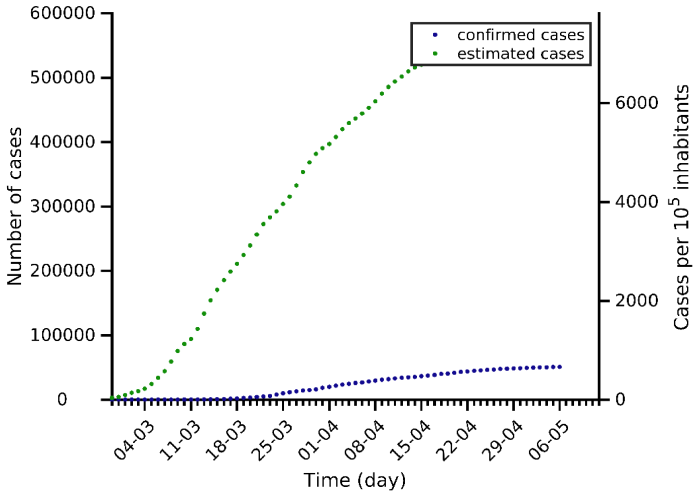


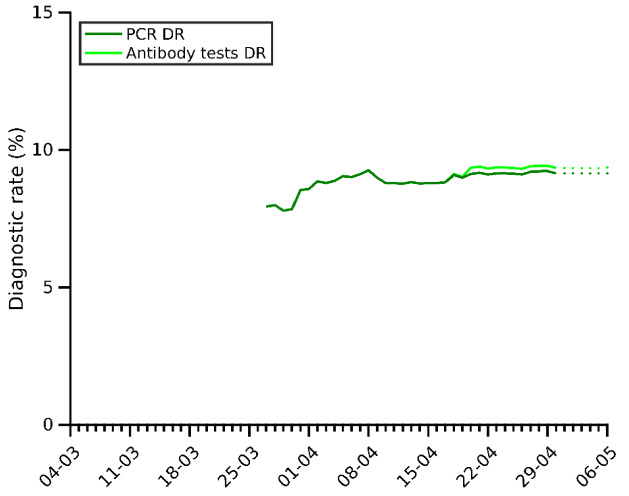


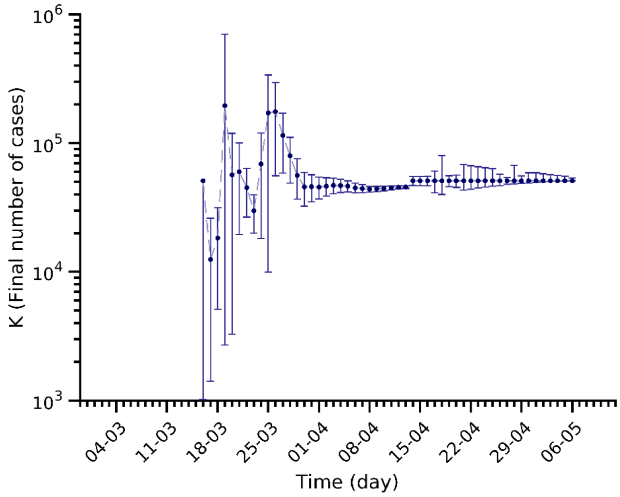


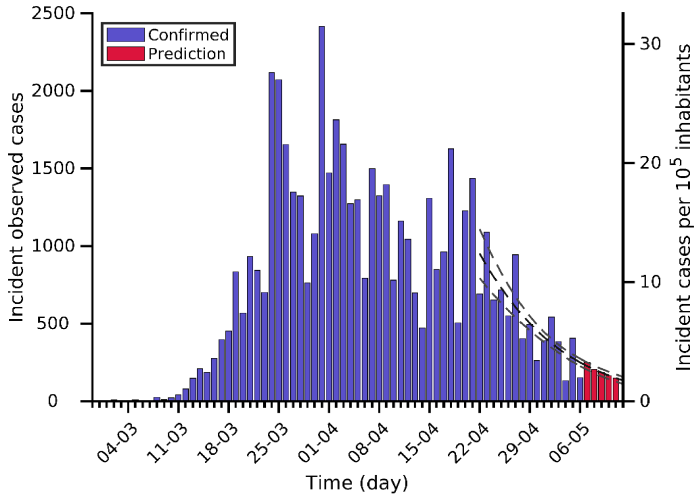
Catalunya 06-05-2020. Population: 7.7M. Current cumulated incidence: 663/10^5

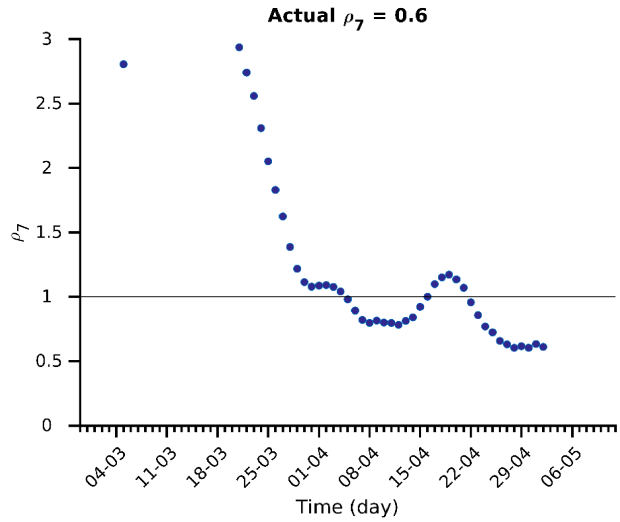


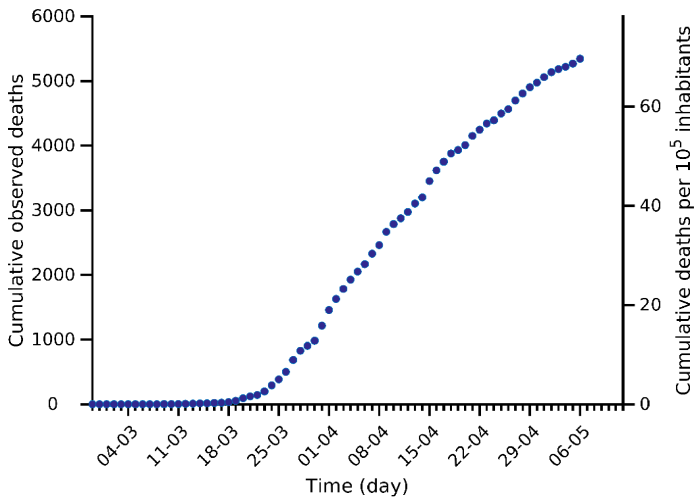


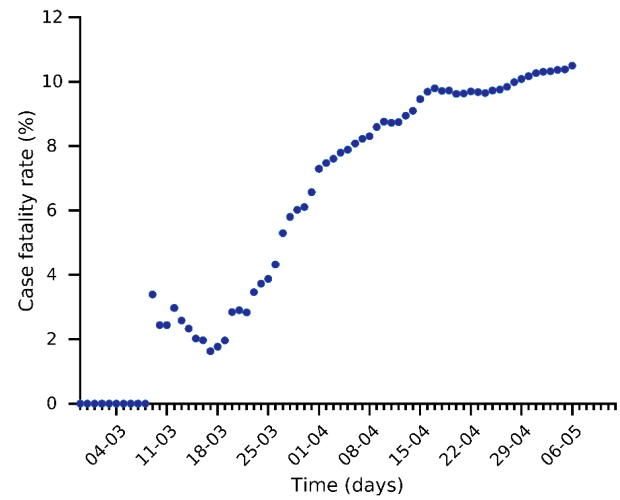




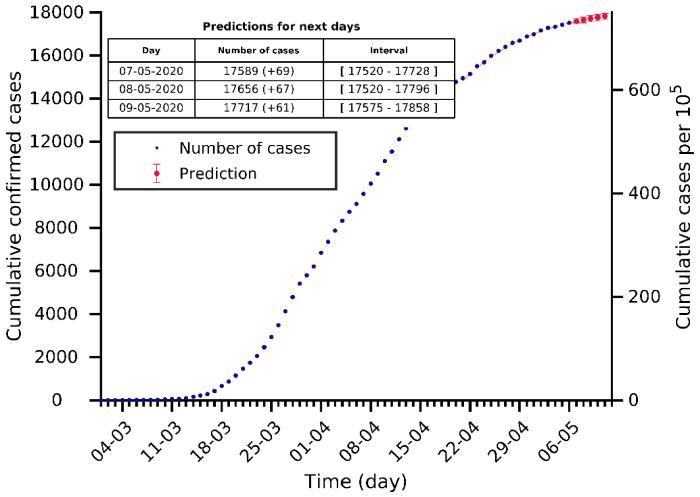


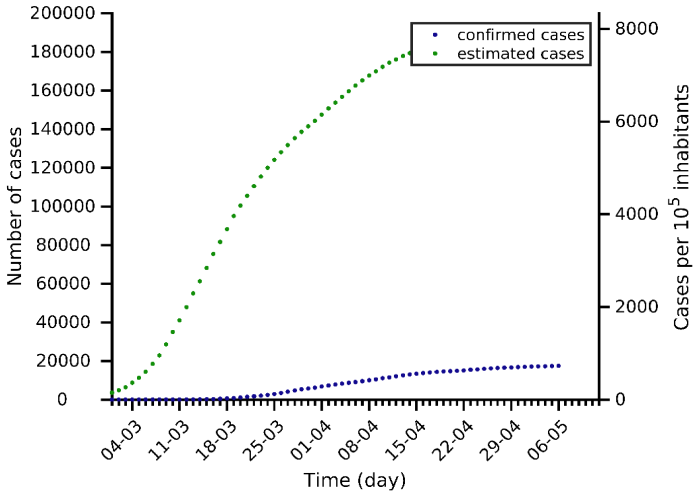


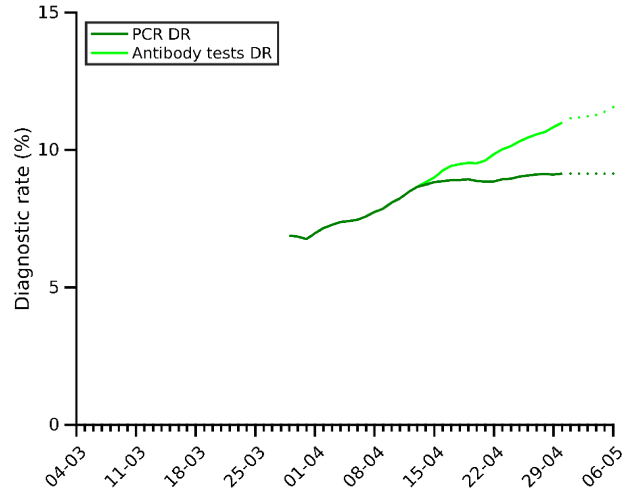


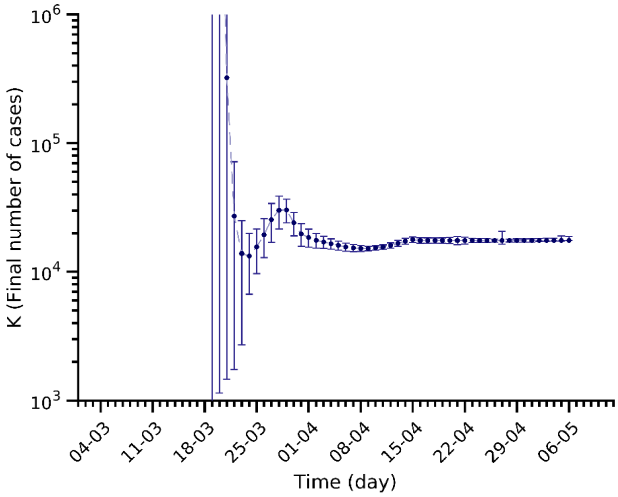


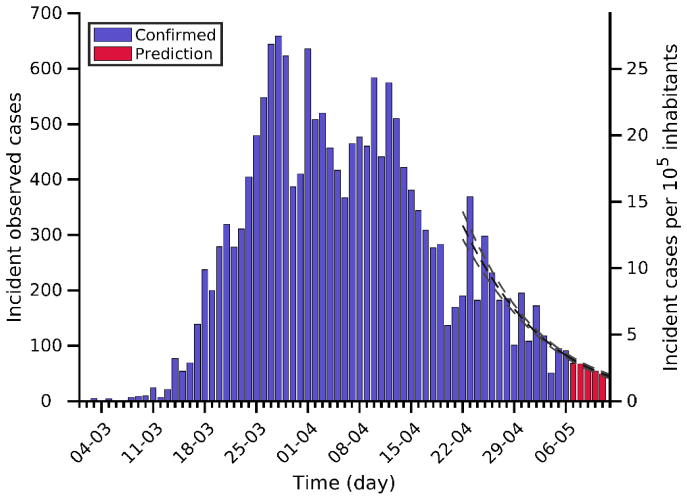
Castilla Leon 06-05-2020. Population: 2.4M. Current cumulated incidence: 730/10^5

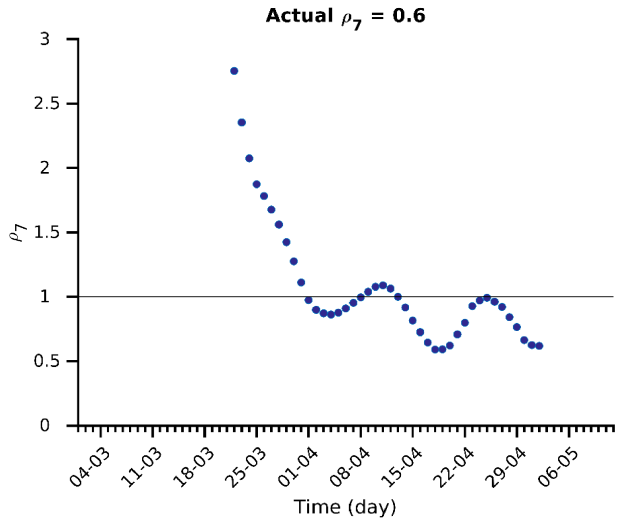


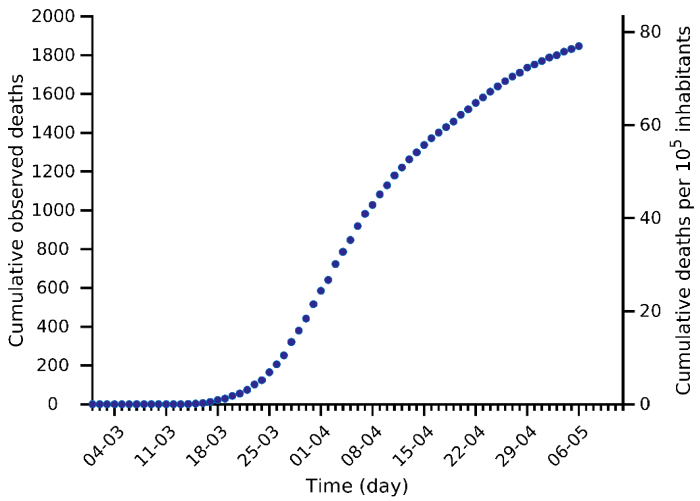


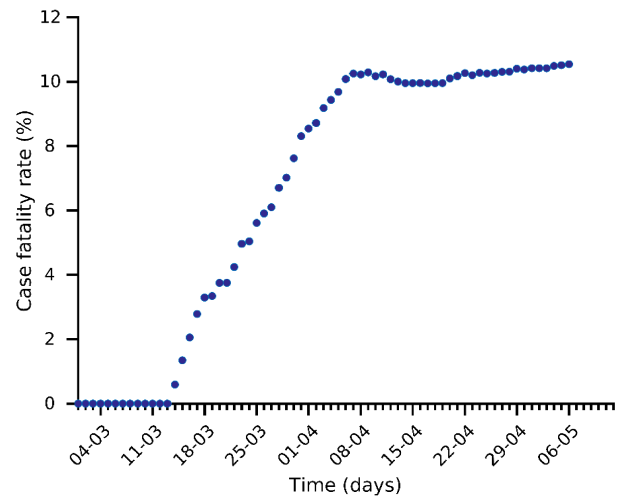




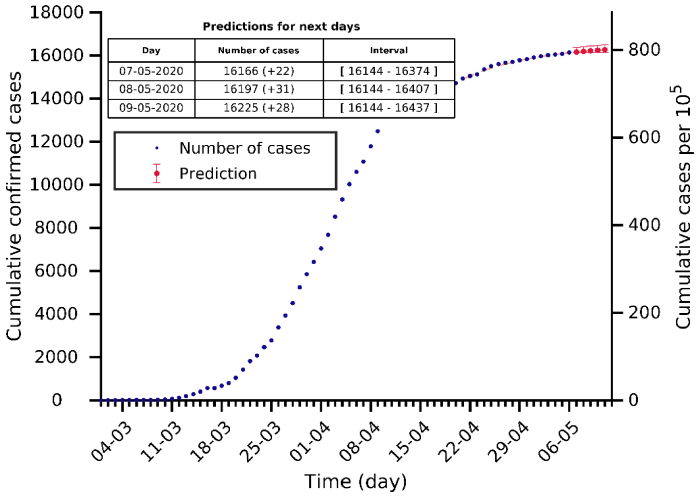


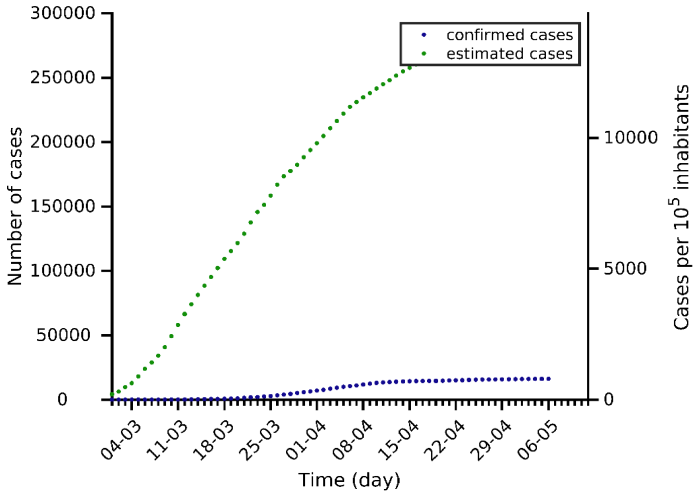


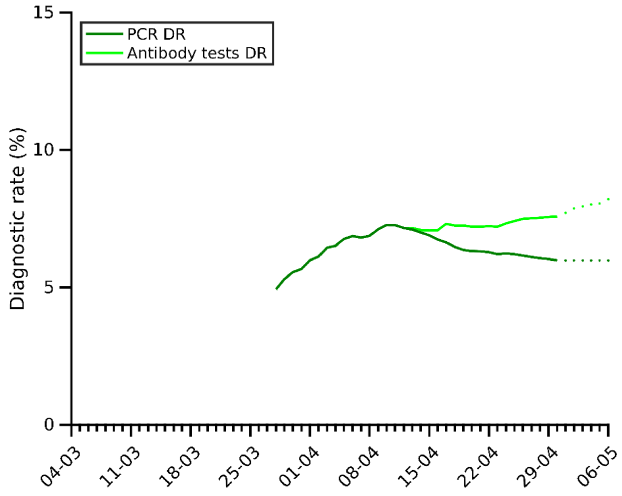


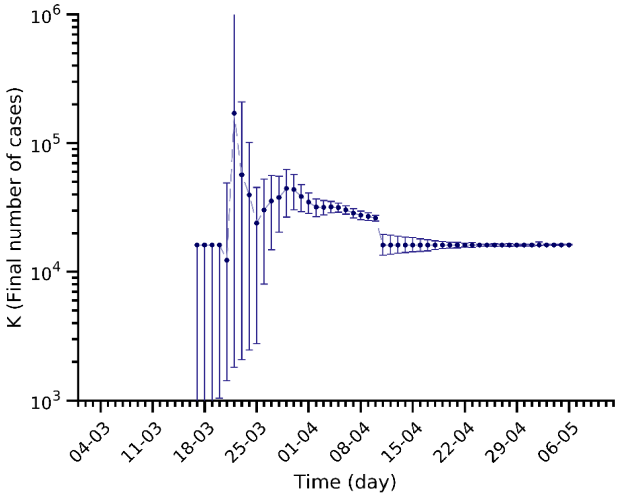


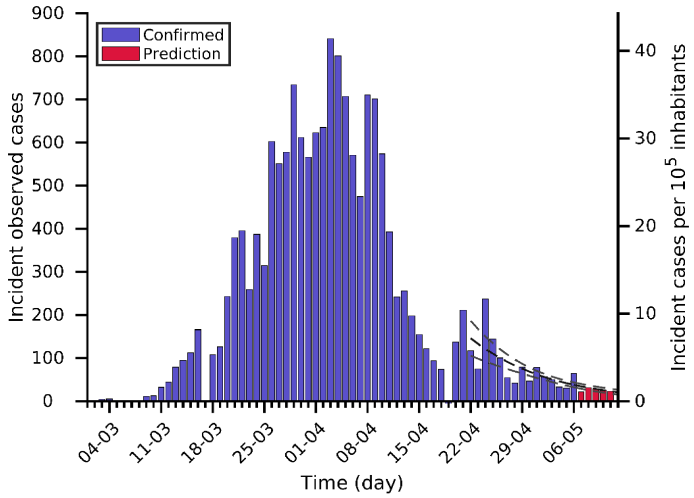
Castilla-La Mancha 06-05-2020. Population: 2.0M. Current cumulated incidence: 79

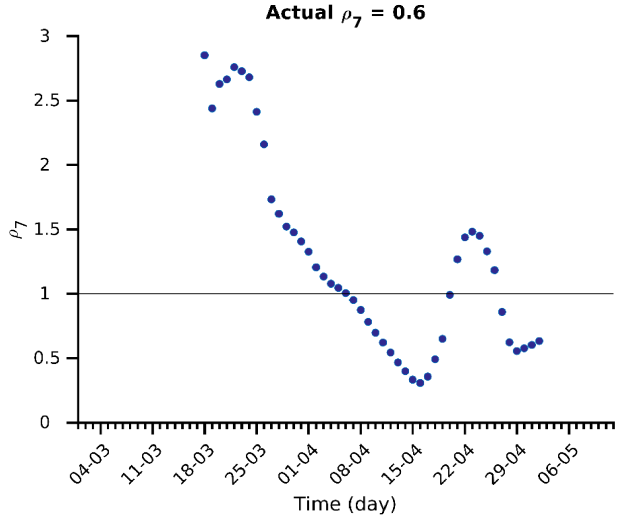


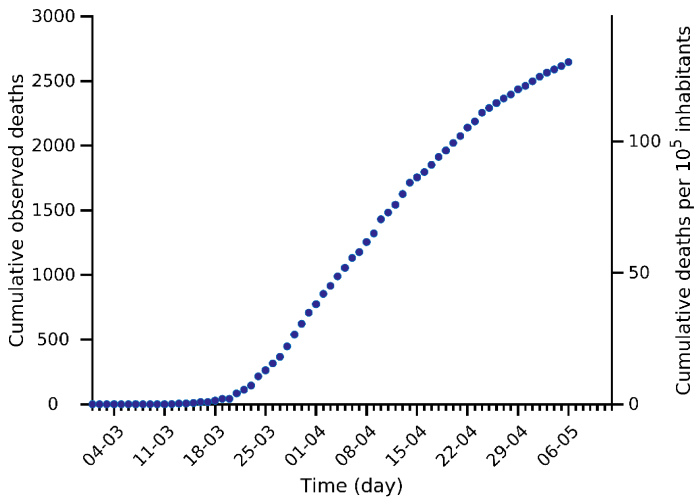


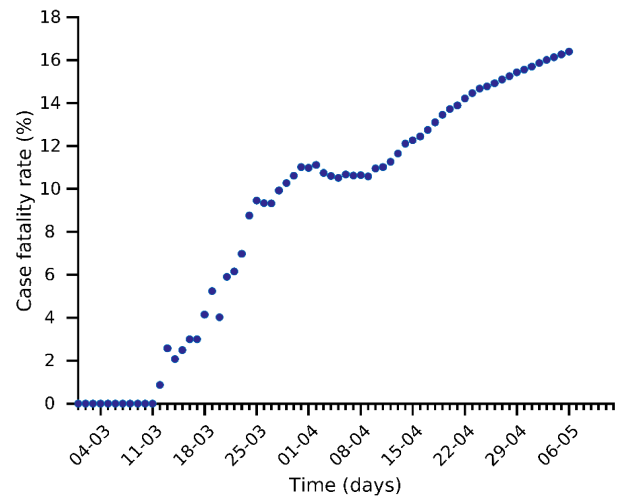




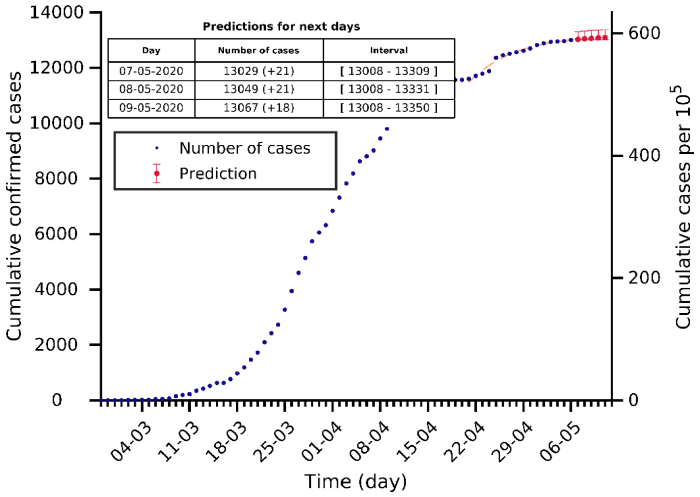


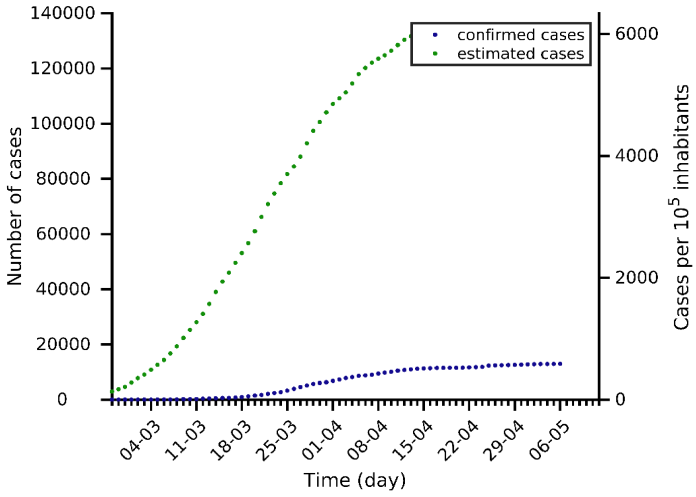


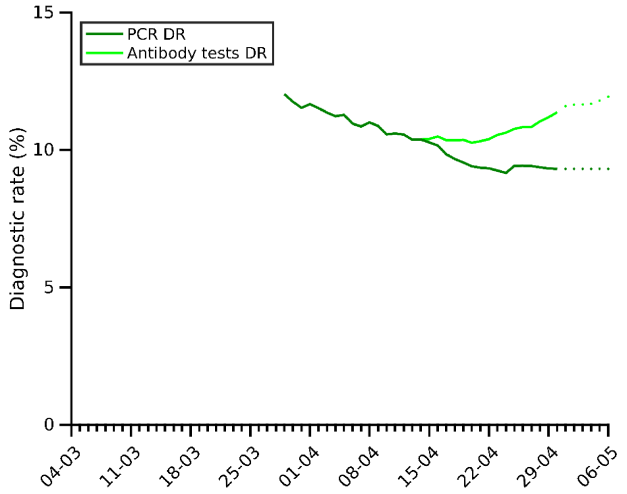


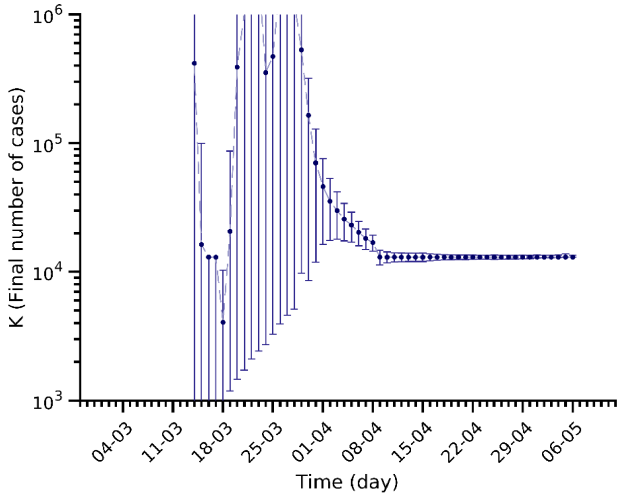


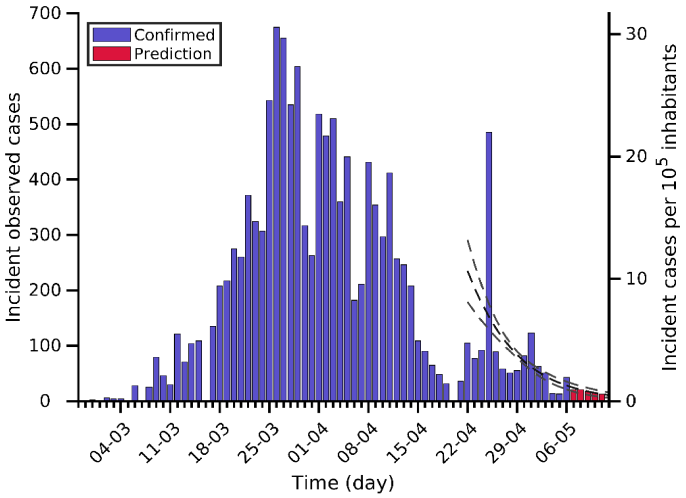
Euskadi 06-05-2020. Population: 2.2M. Current cumulated incidence: 589/10^5

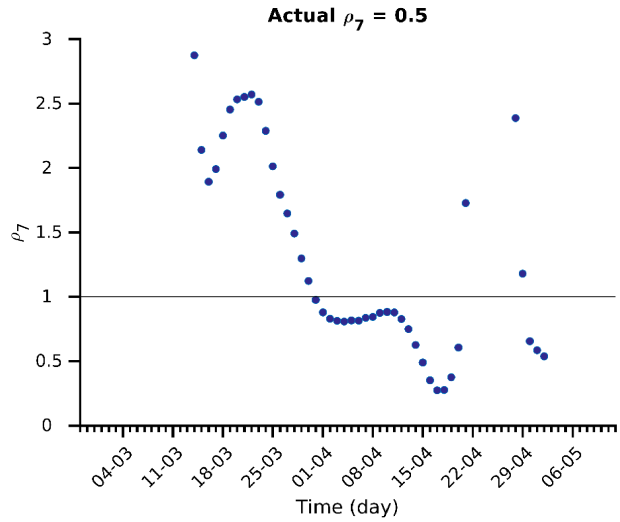


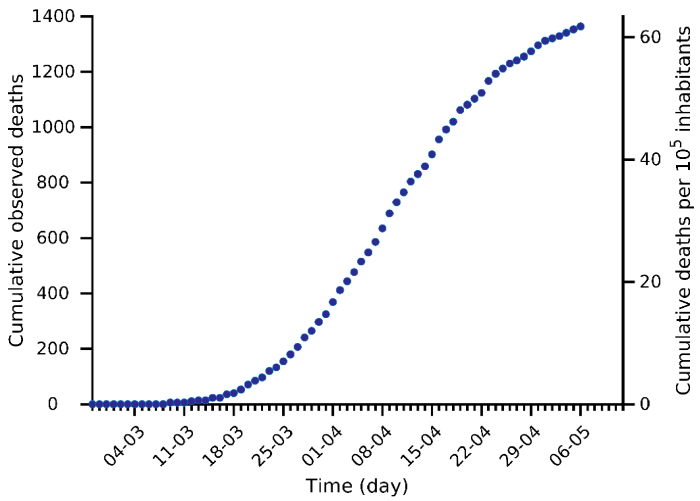


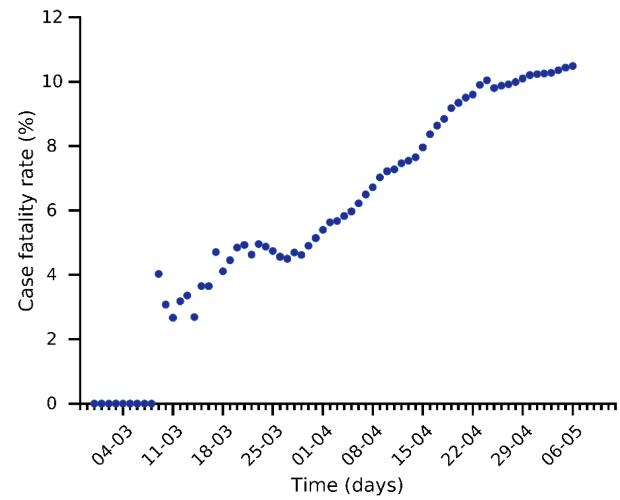




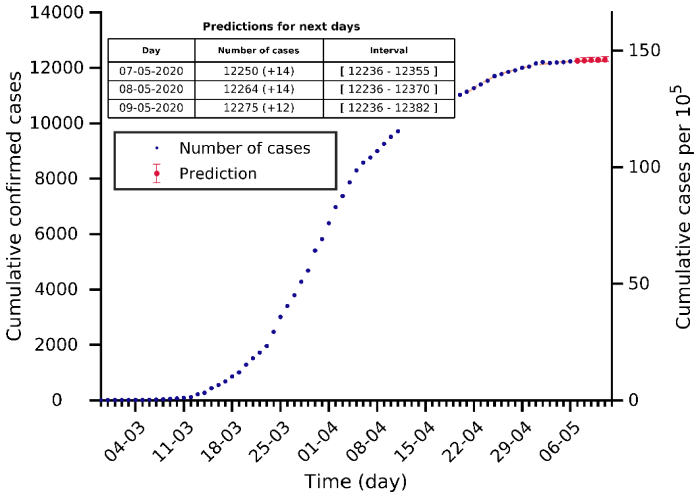


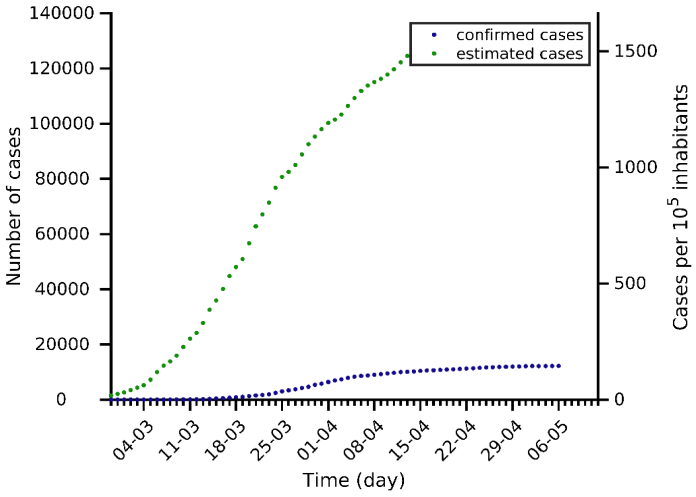


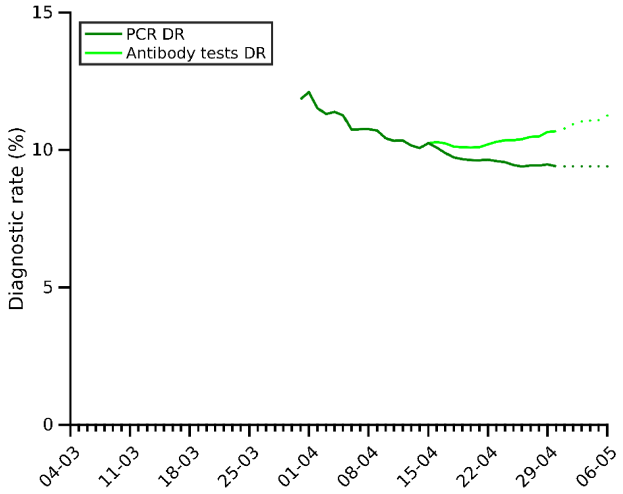


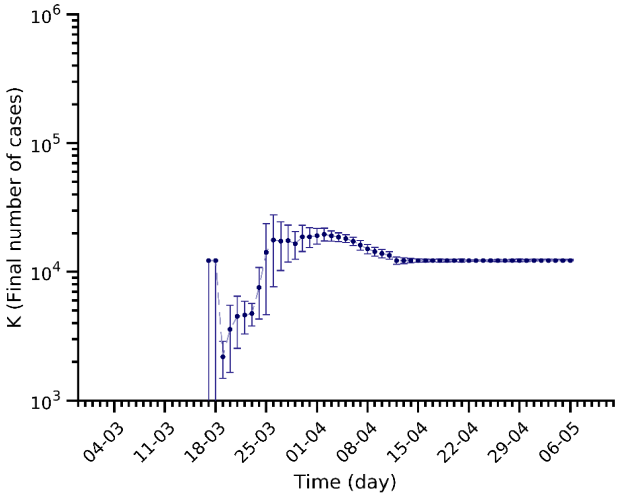


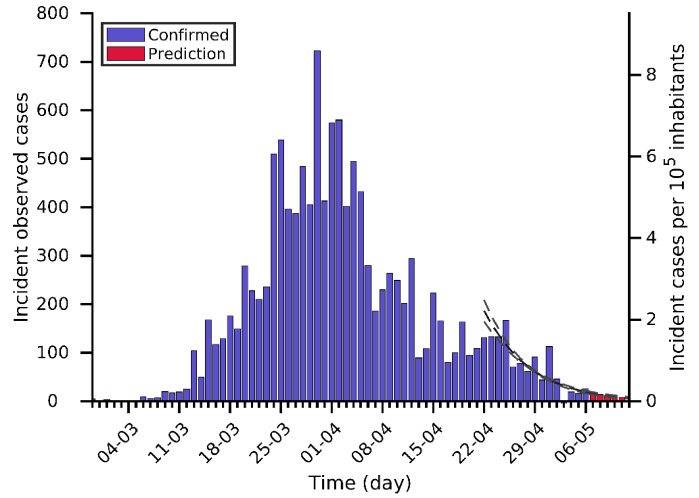
Andalucia 06-05-2020. Population: 8.4M. Current cumulated incidence: 145/10^5

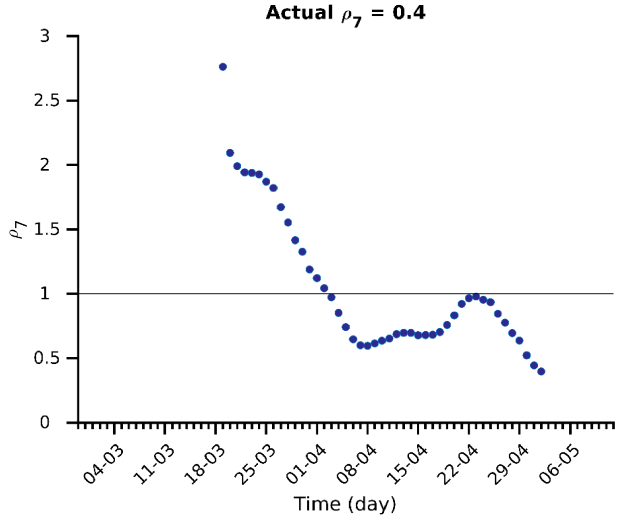


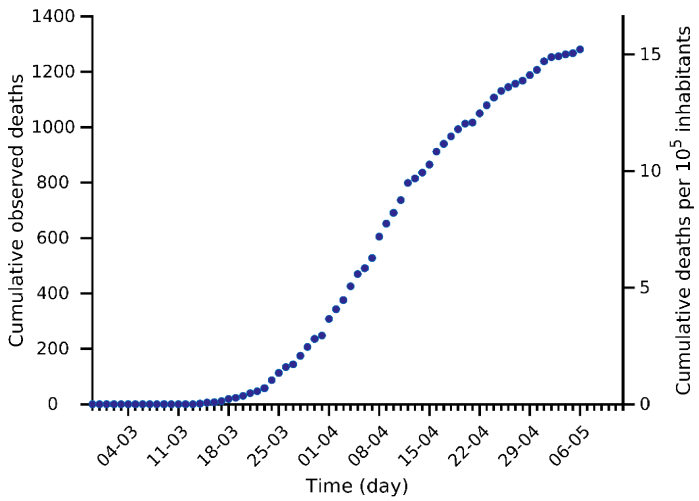


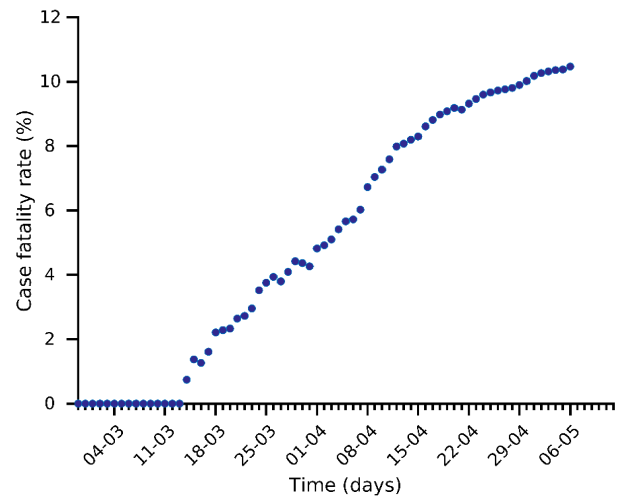




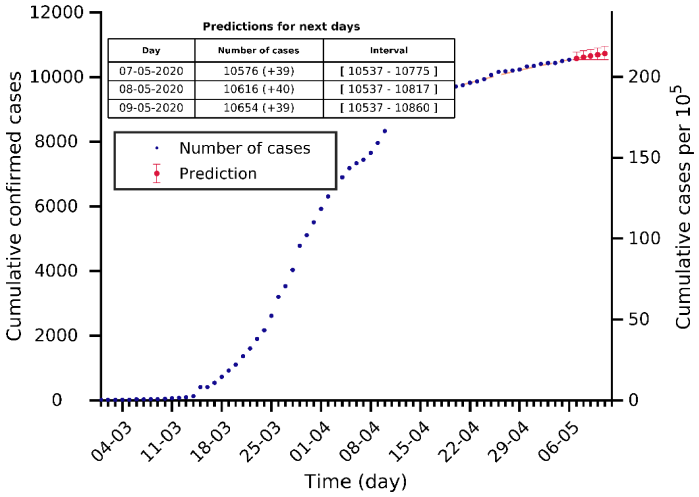


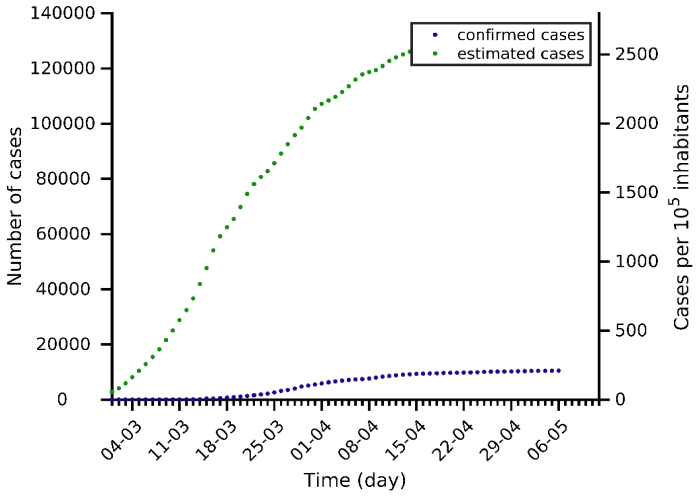


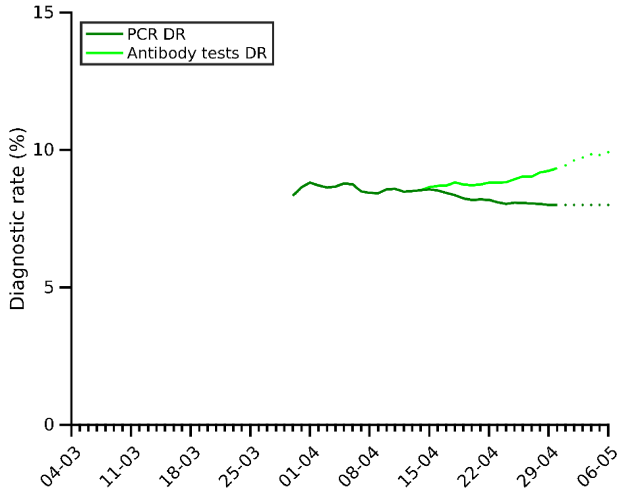


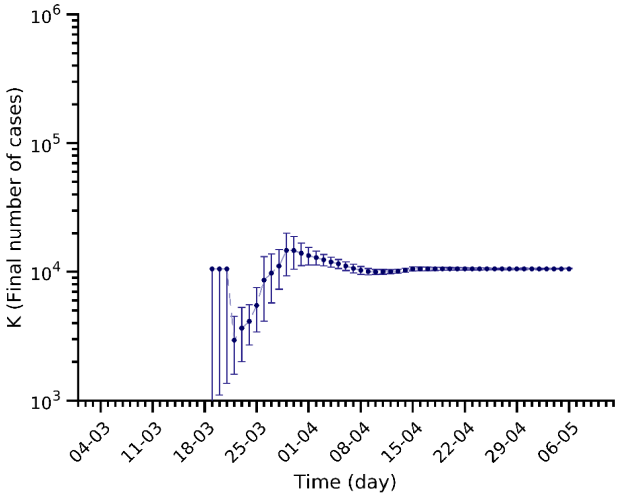


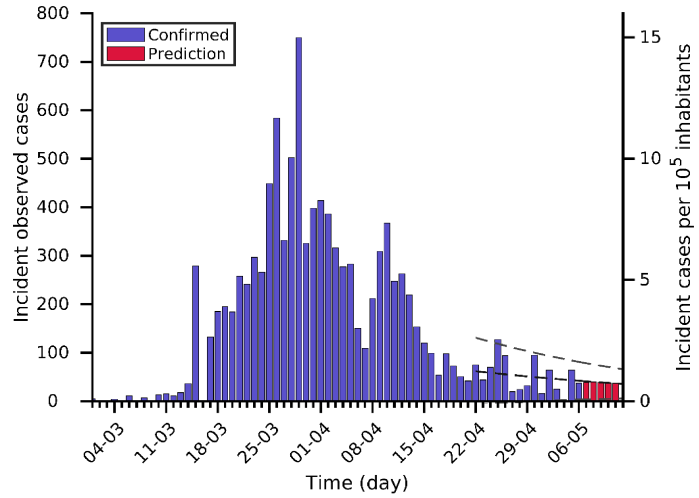
C Valenciana 06-05-2020. Population: 5.0M. Current cumulated incidence: 211/10^5

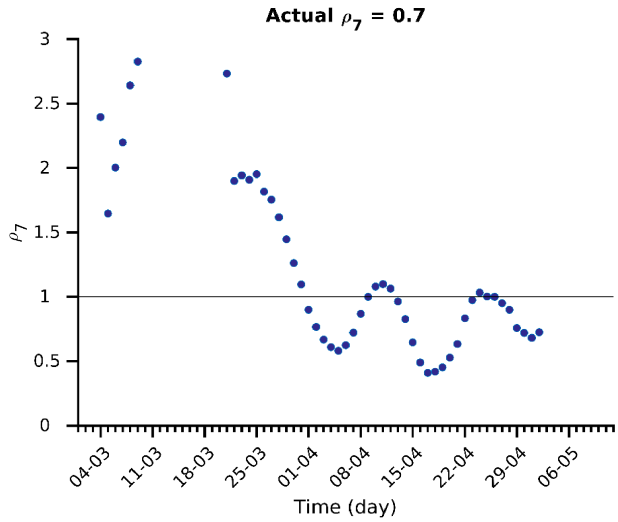


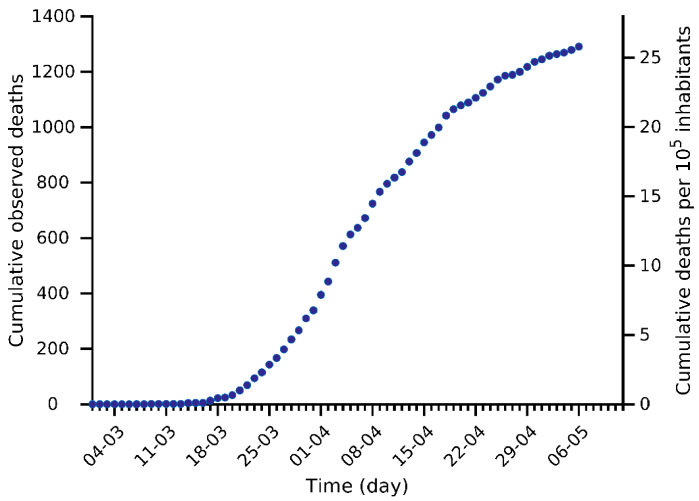


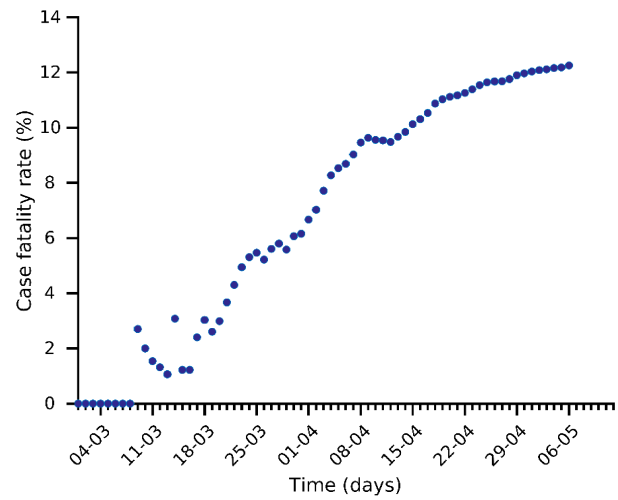




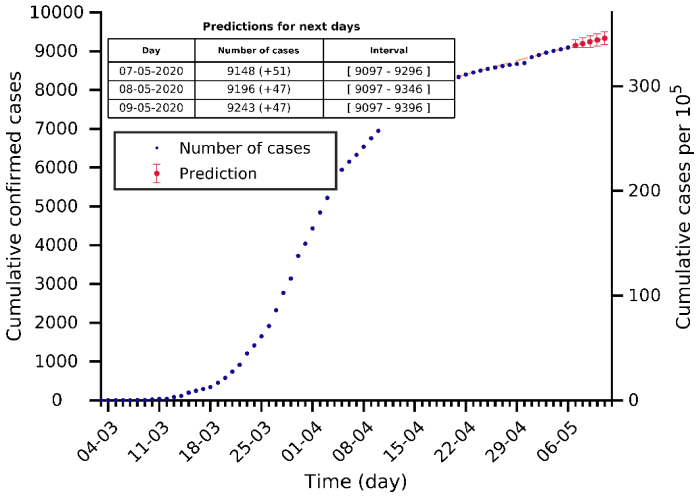


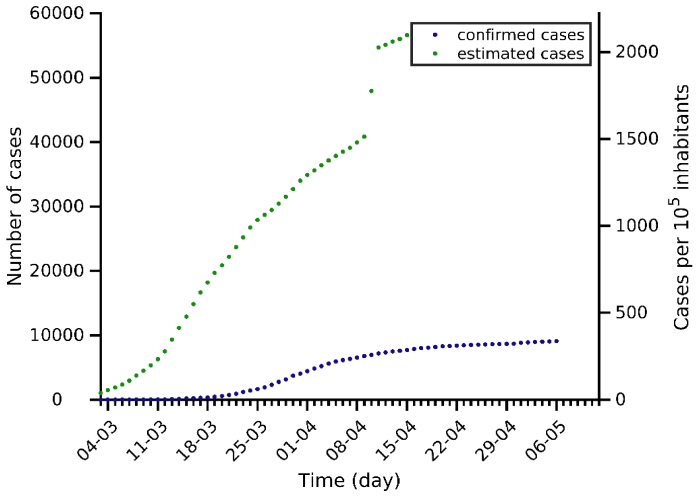


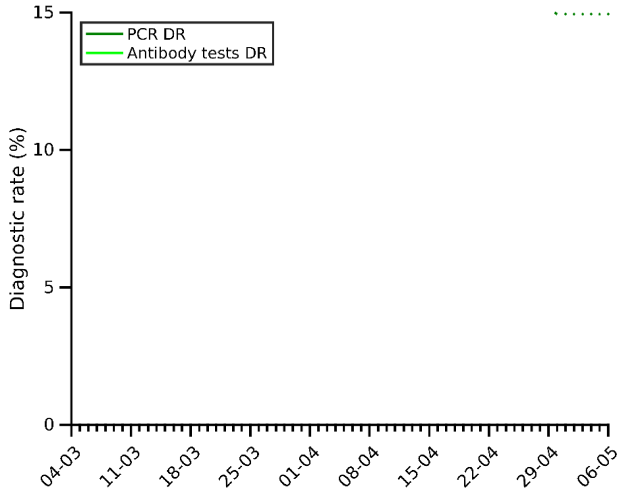


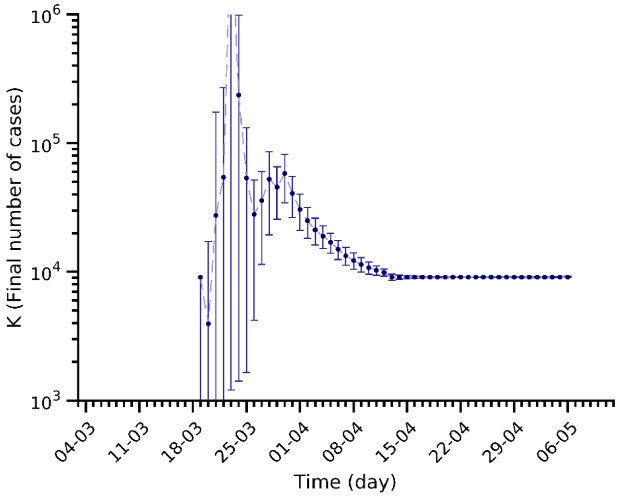


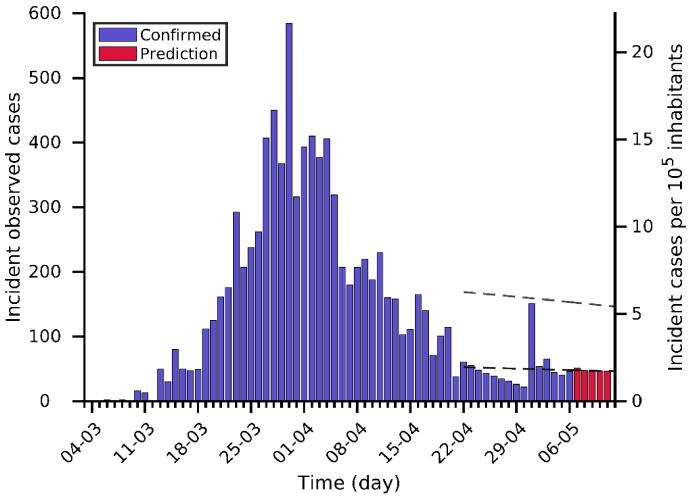
Galicia 06-05-2020. Population: 2.7M. Current cumulated incidence: 337/10⁵

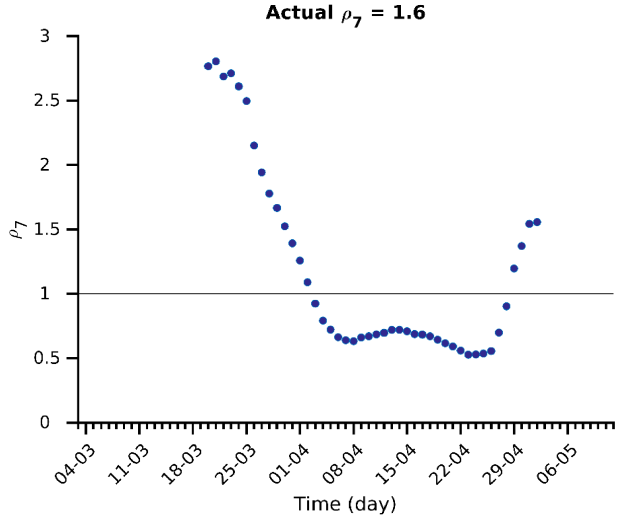


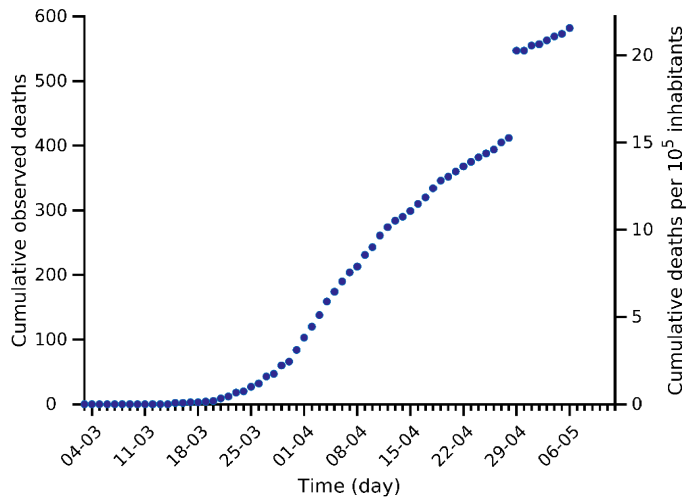


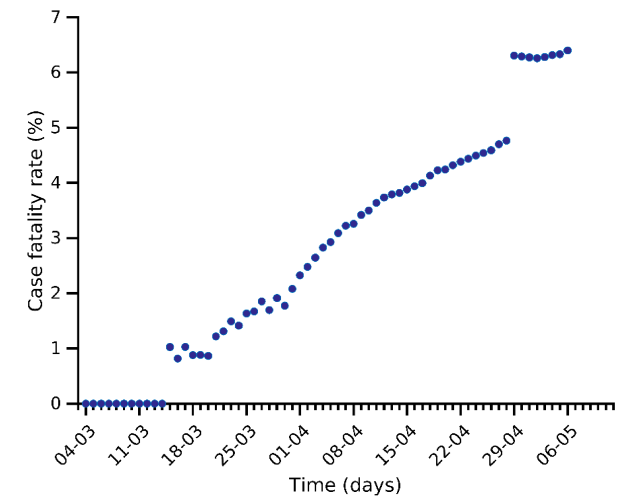




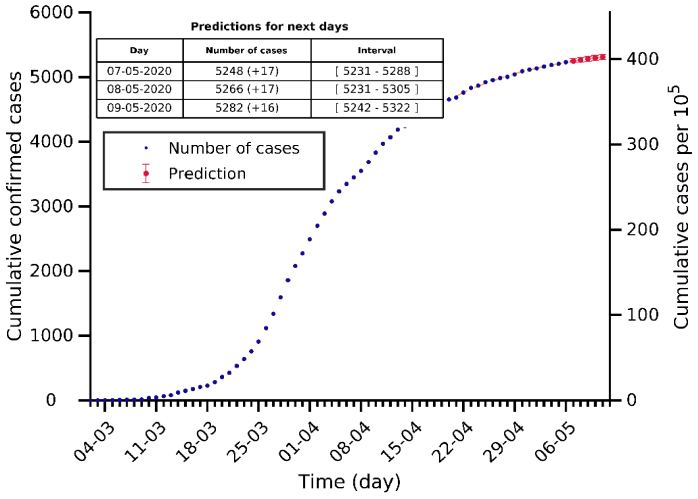


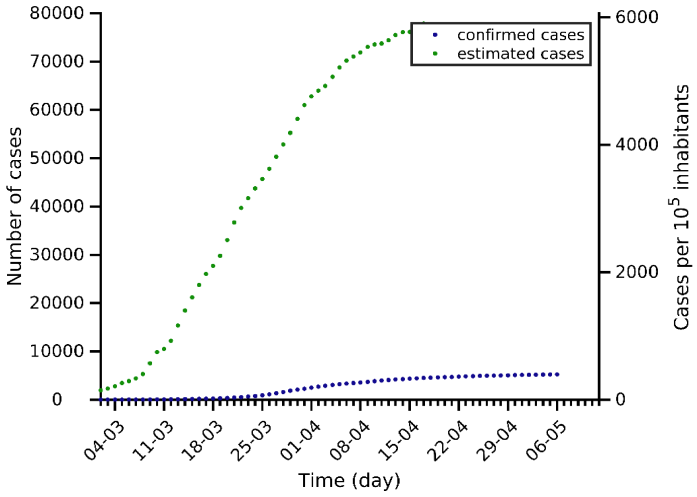


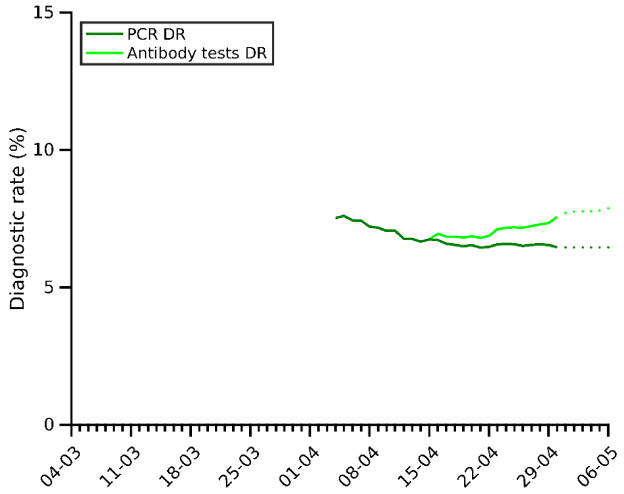


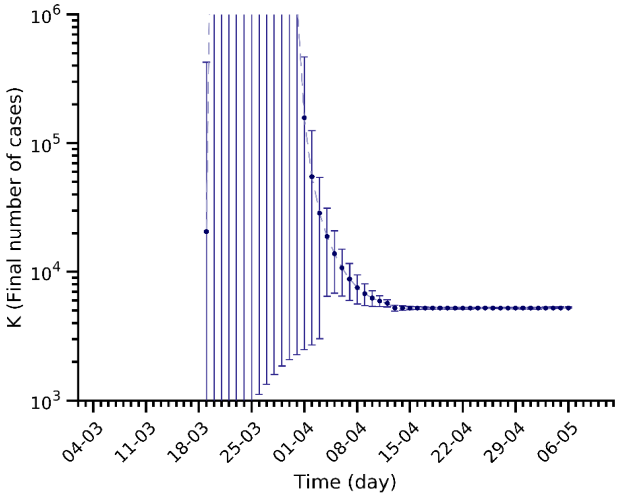


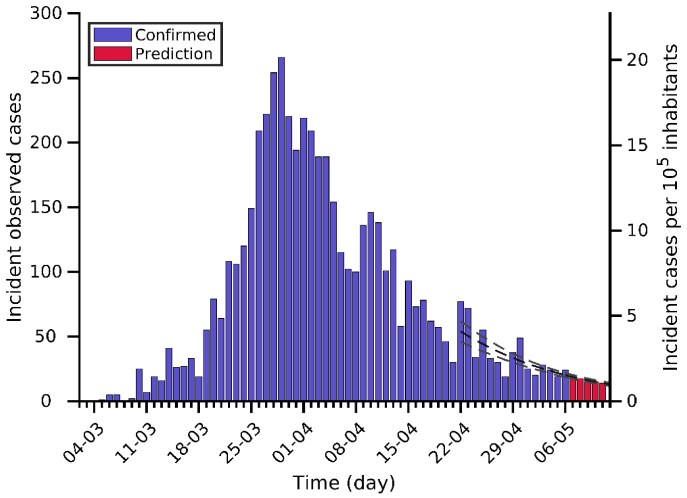
Aragon 06-05-2020. Population: 1.3M. Current cumulated incidence: 397/10^5

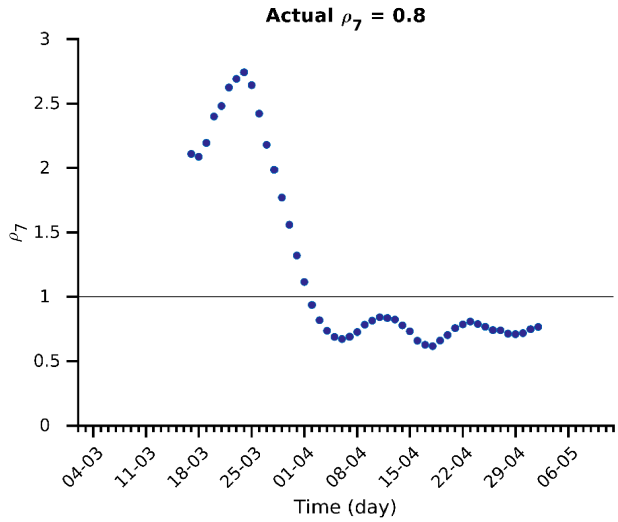


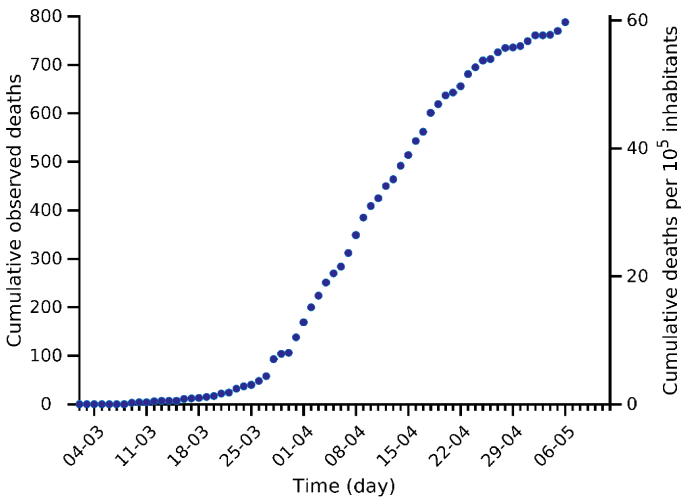


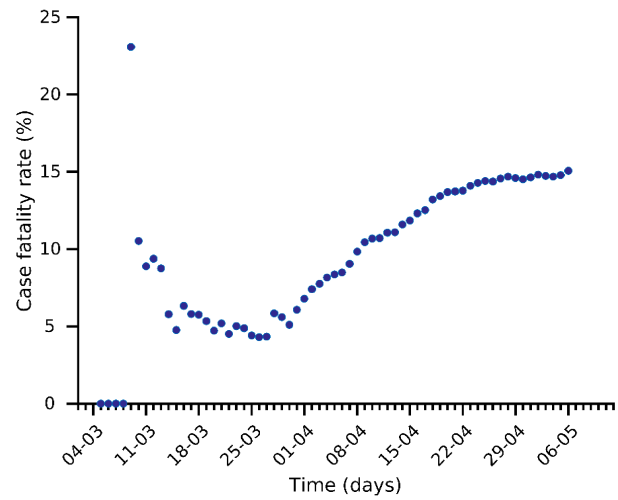




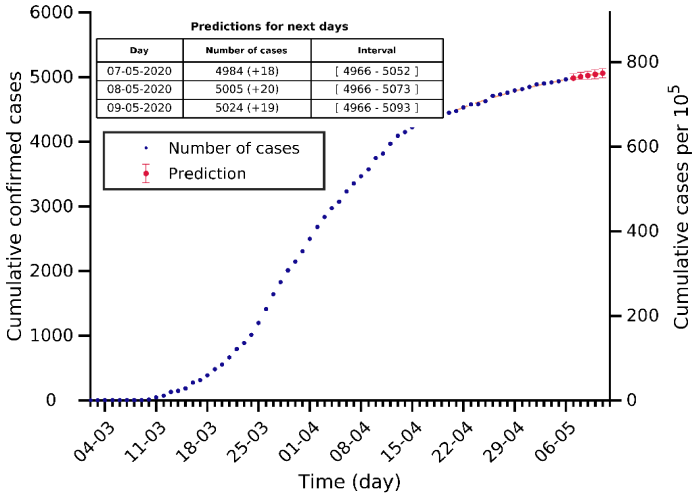


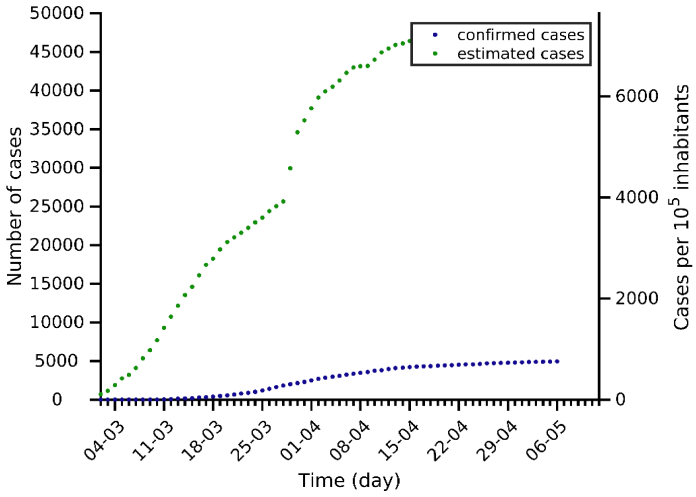


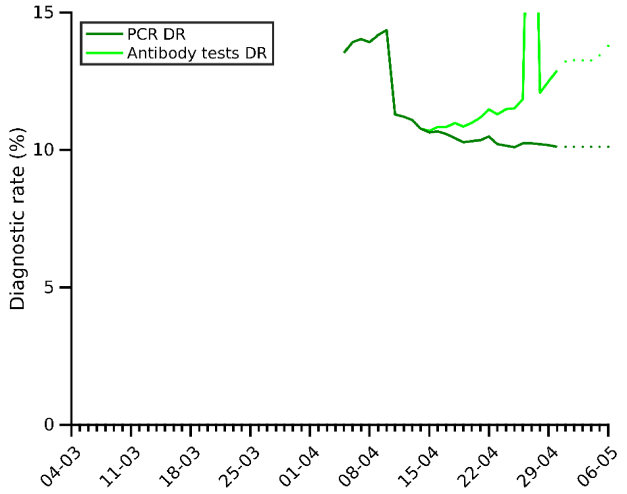


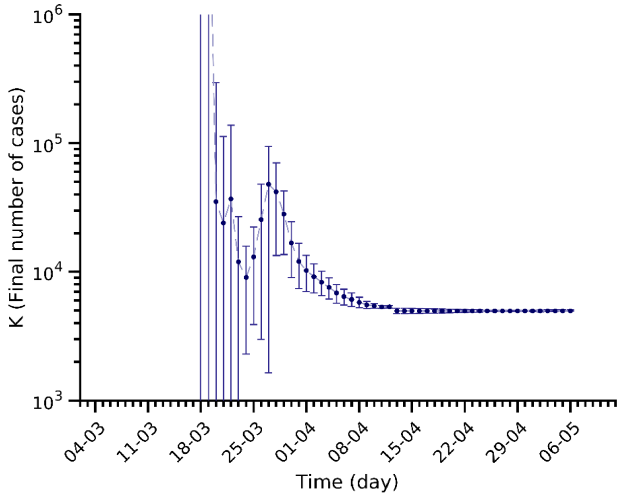


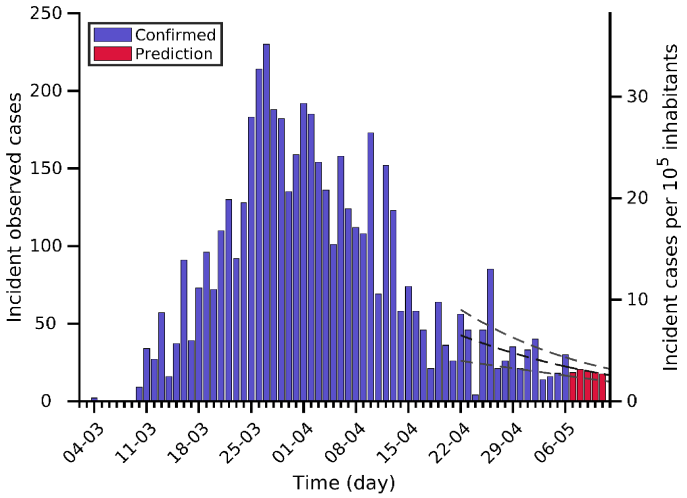
Navarra 06-05-2020. Population: 0.7M. Current cumulated incidence: 759/10^5

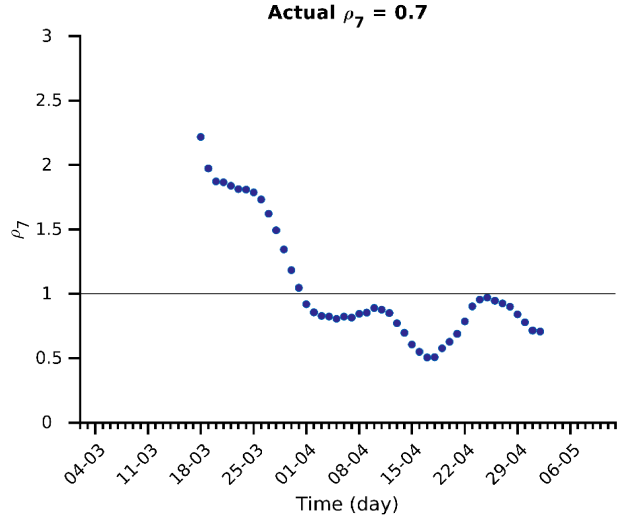


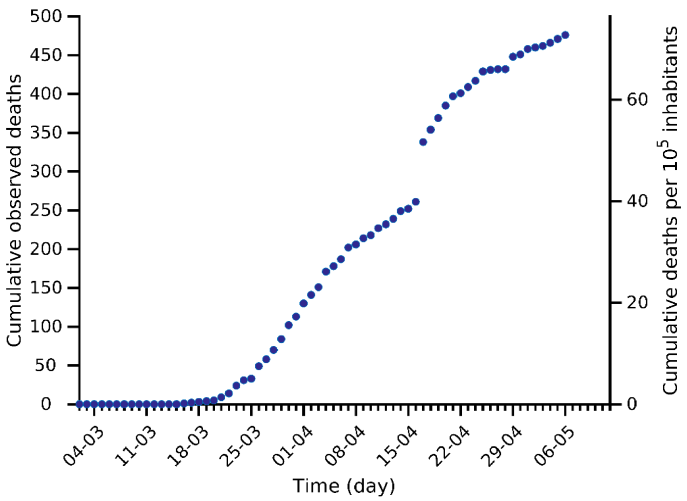


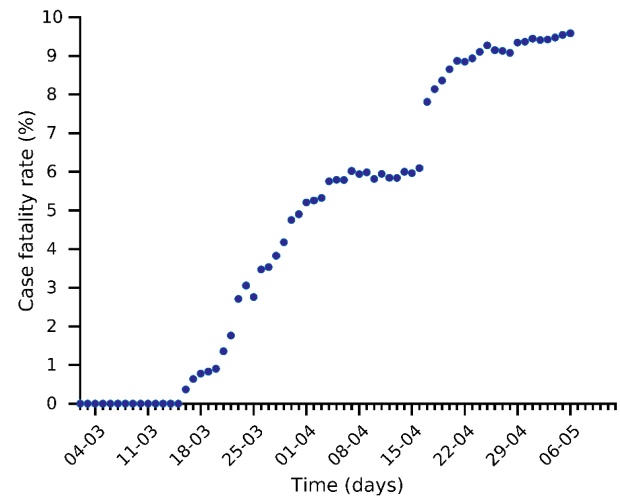




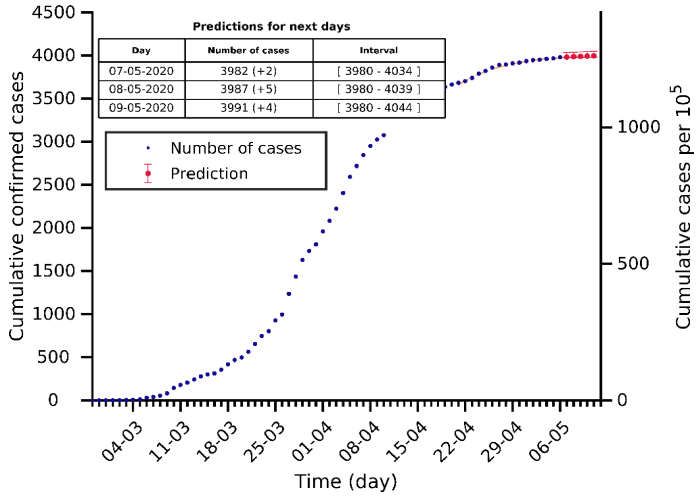


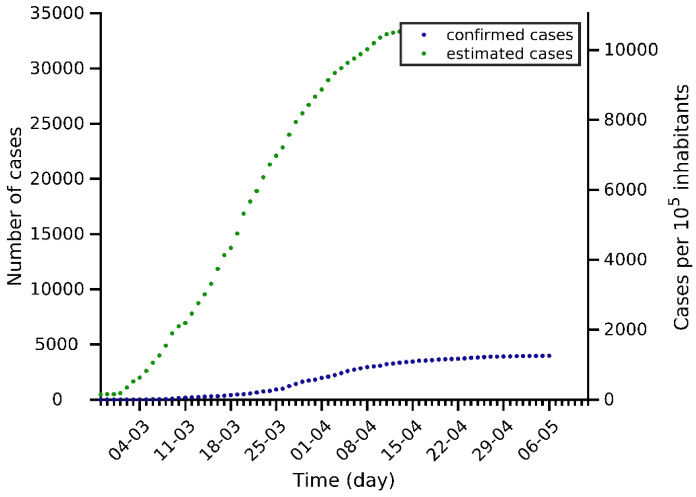


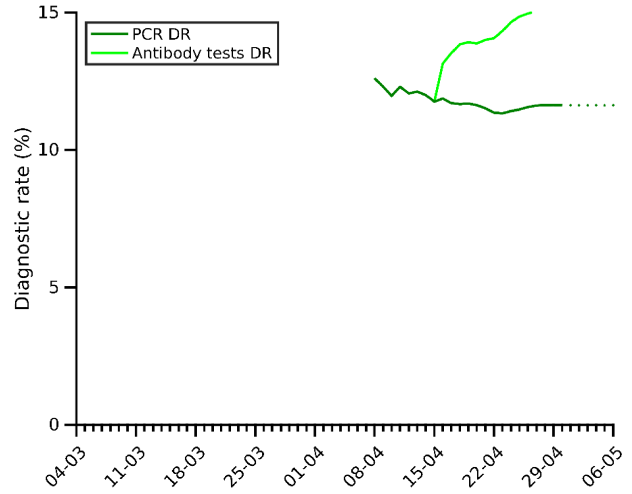


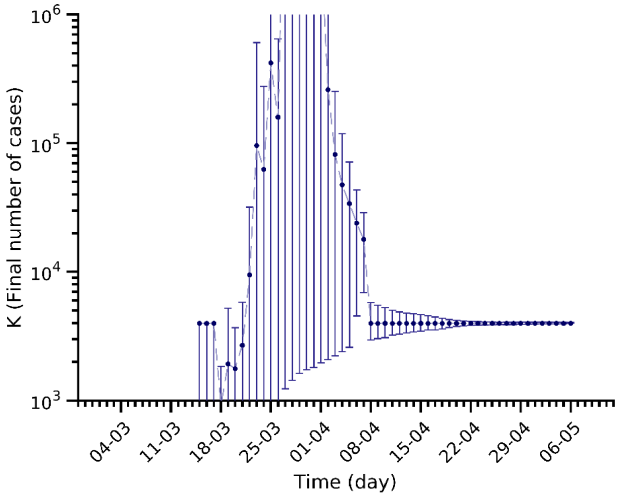


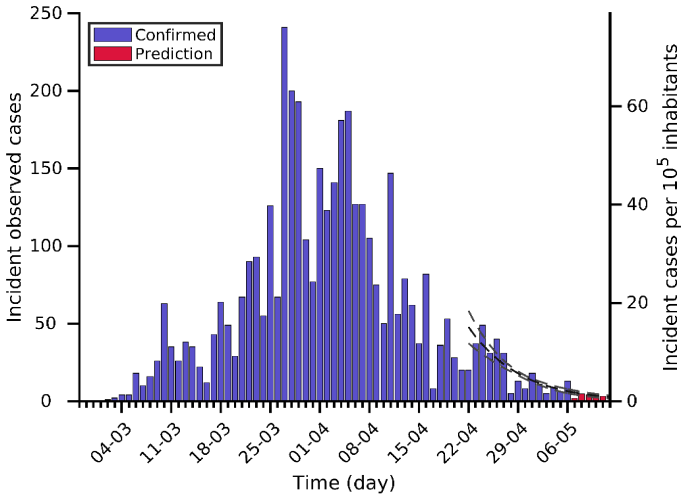
La Rioja 06-05-2020. Population: 0.3M. Current cumulated incidence: 1256/10^5

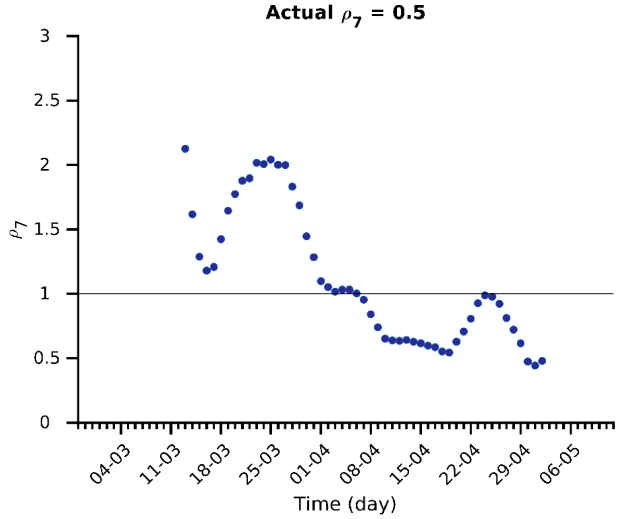


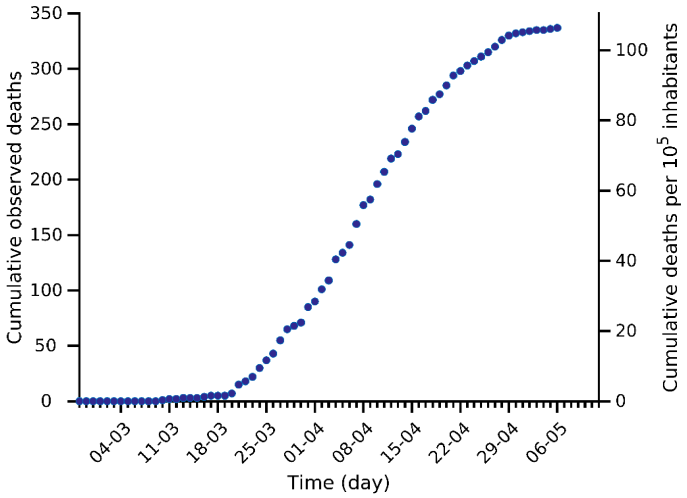


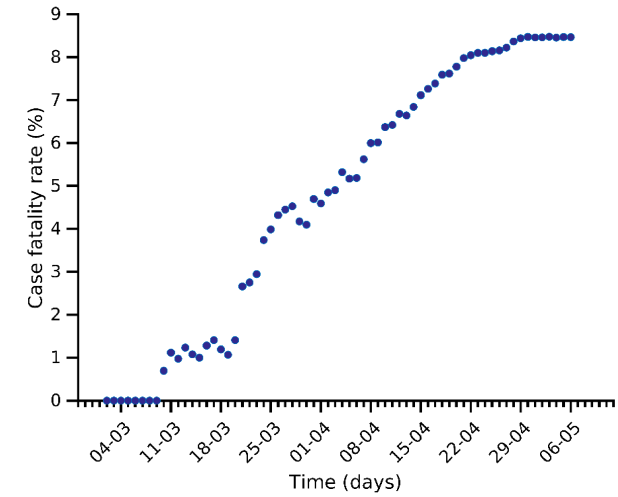




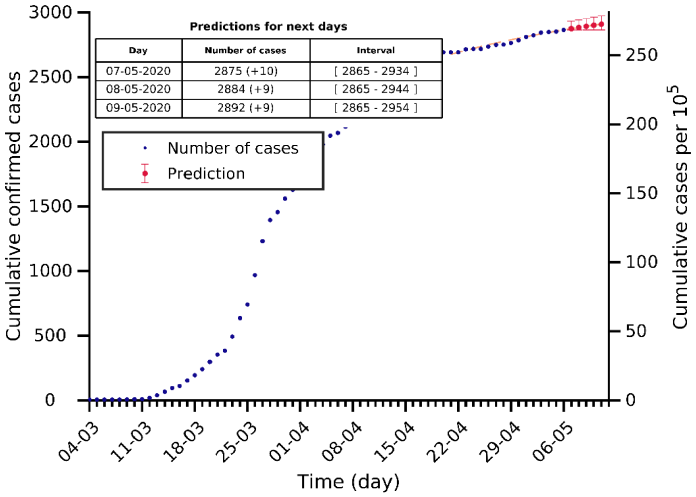


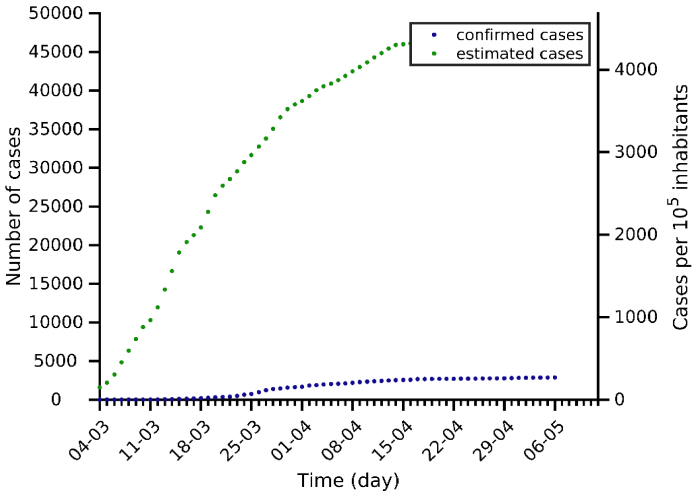


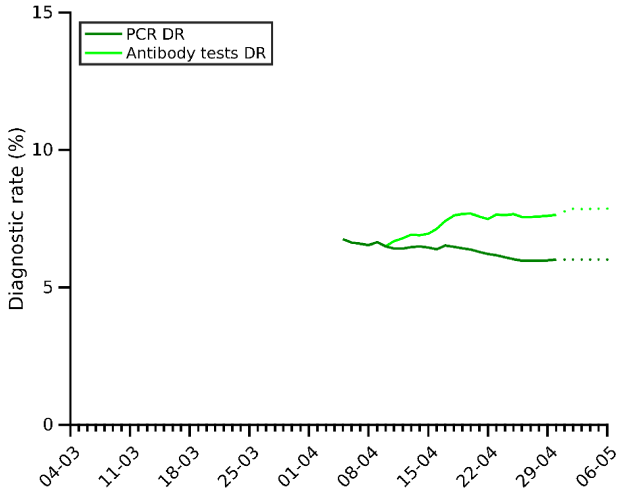


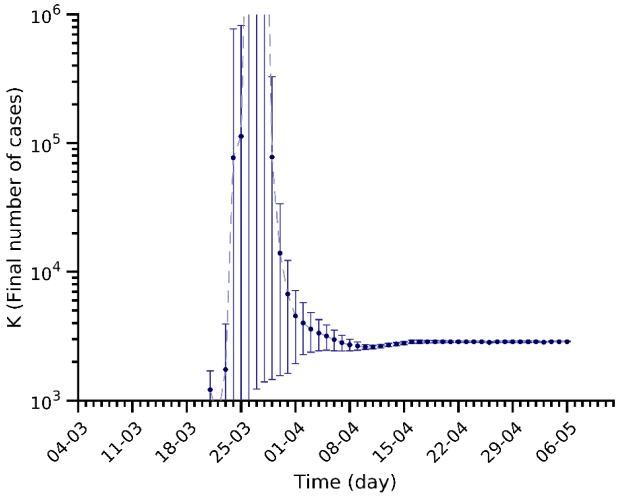


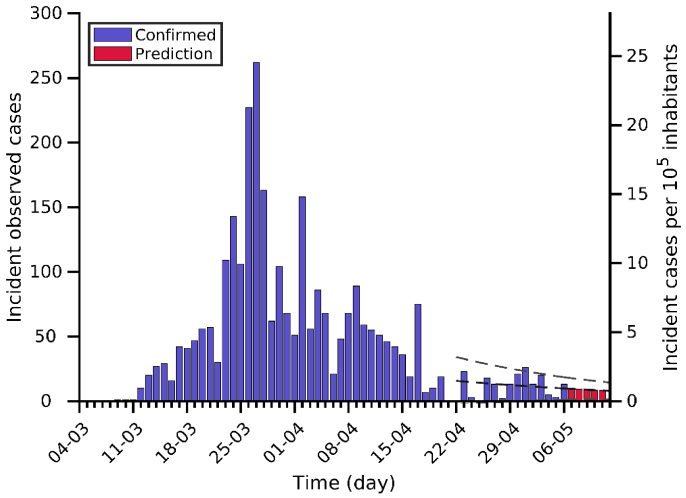
Extremadura 06-05-2020. Population: 1.1M. Current cumulated incidence: 268/10^5

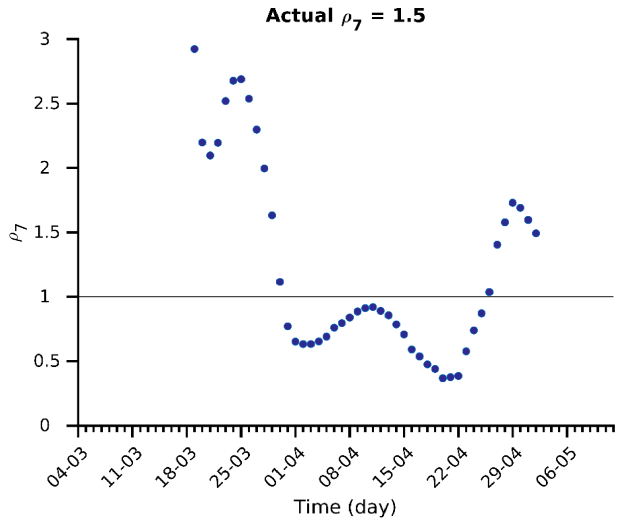


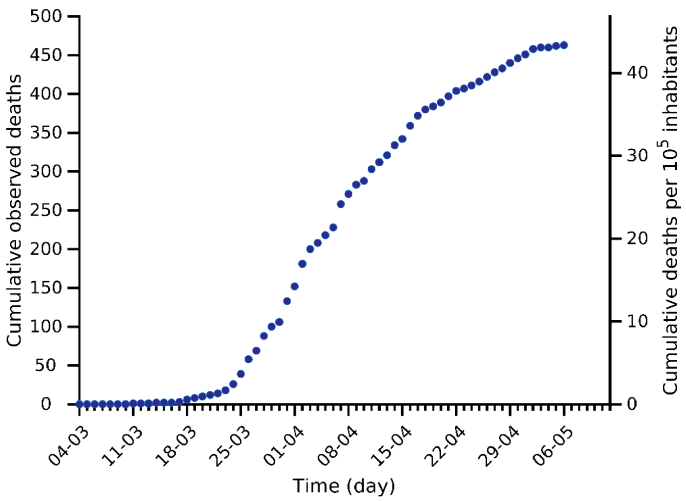


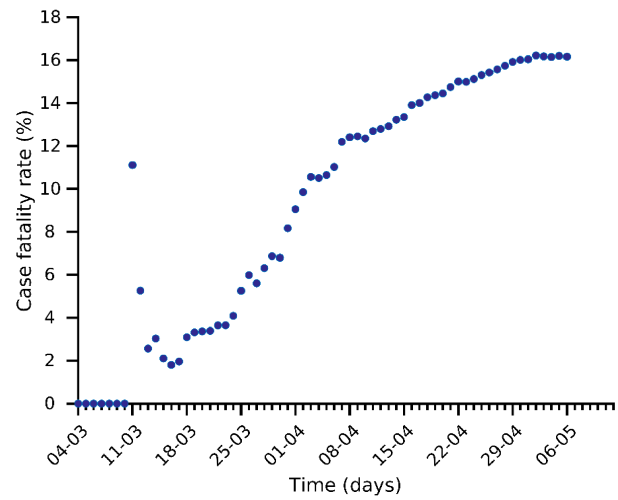




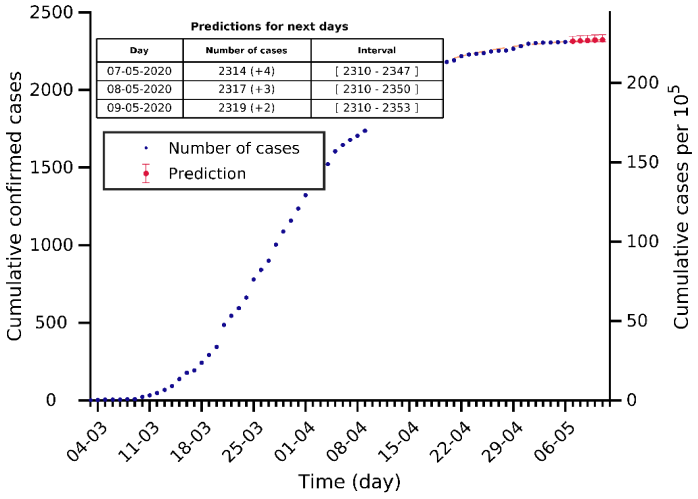


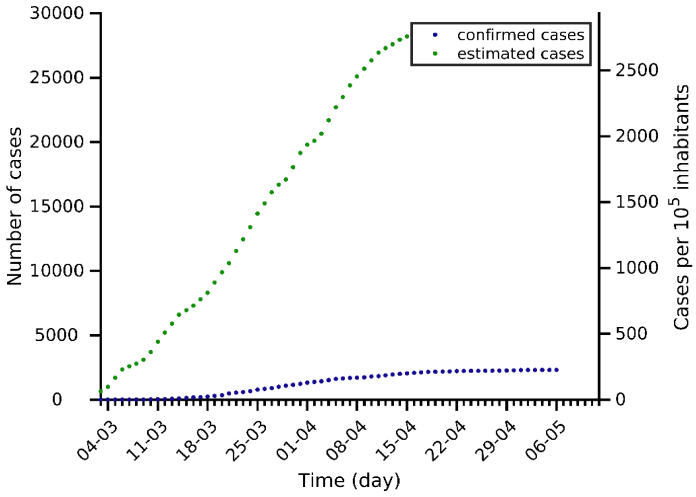


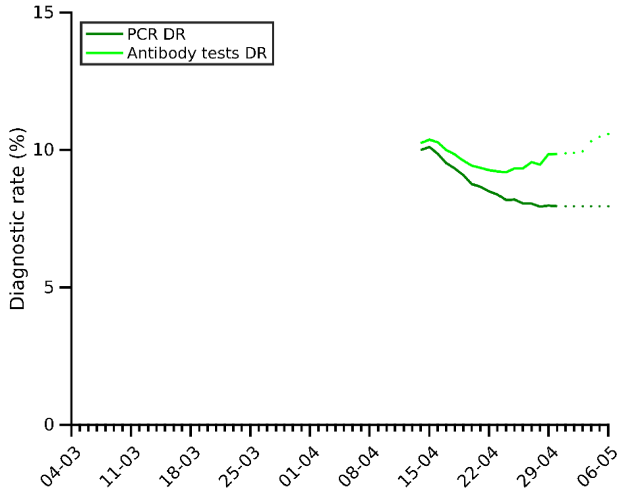


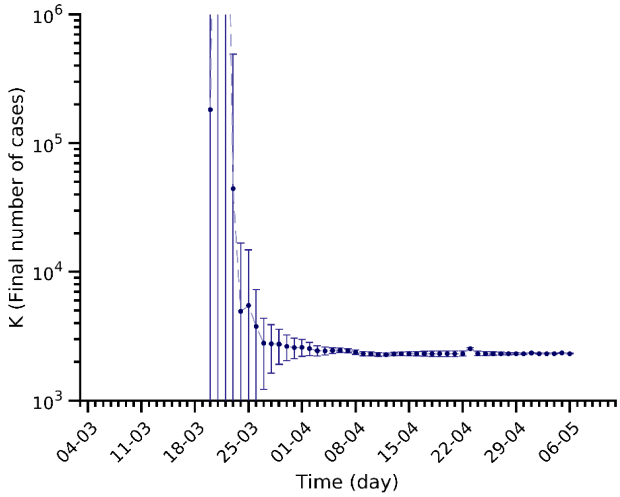


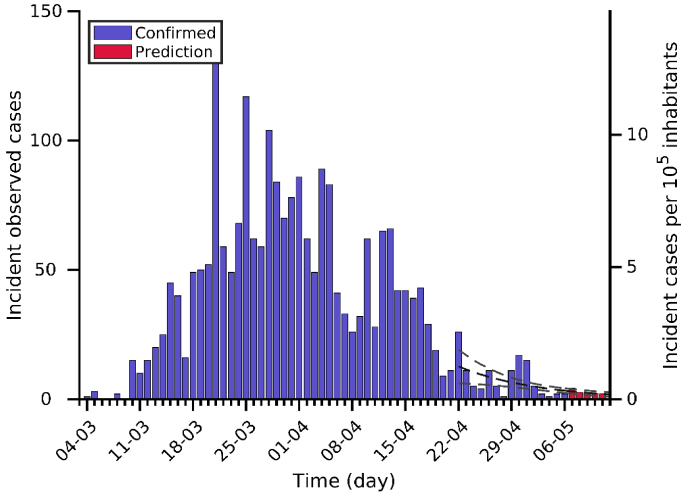
Asturias 06-05-2020. Population: 1.0M. Current cumulated incidence: 226/10⁵

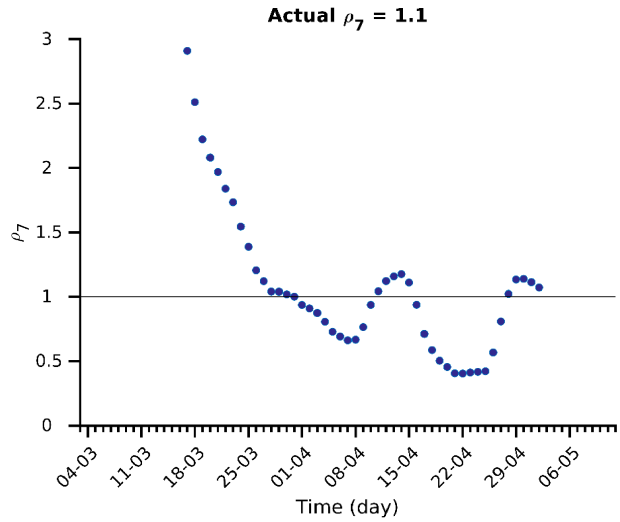


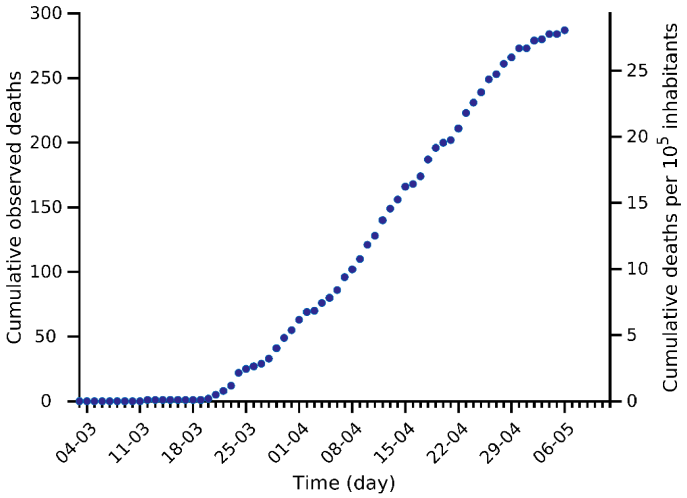


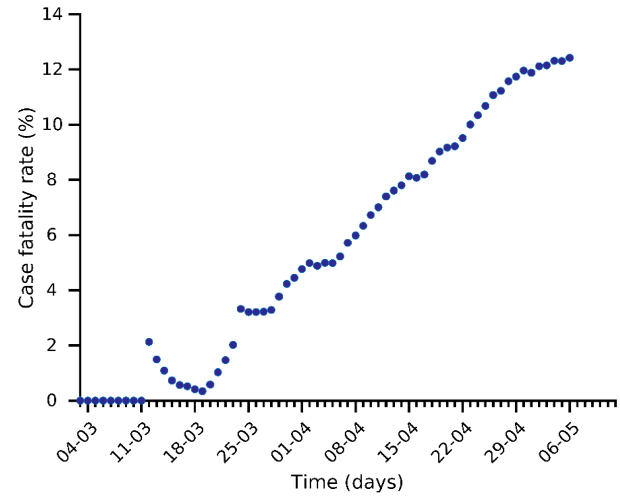




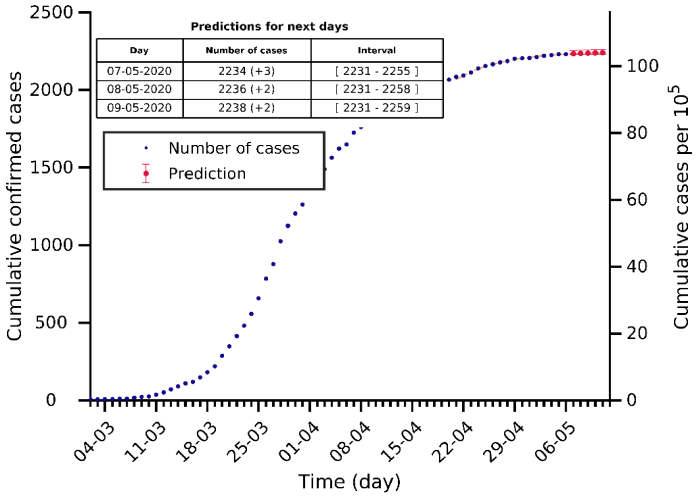


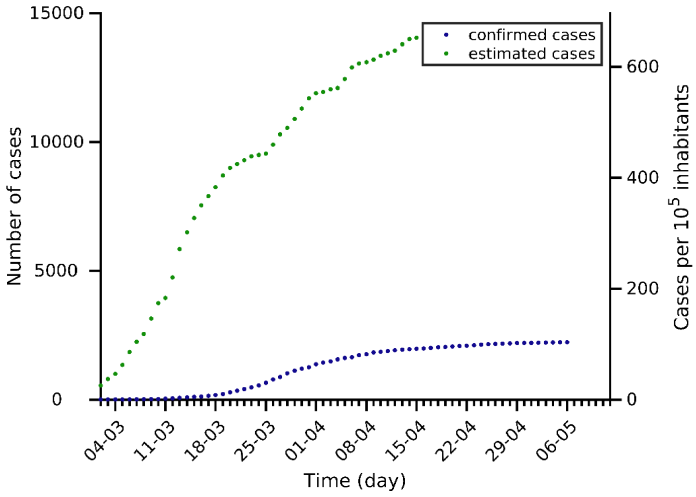


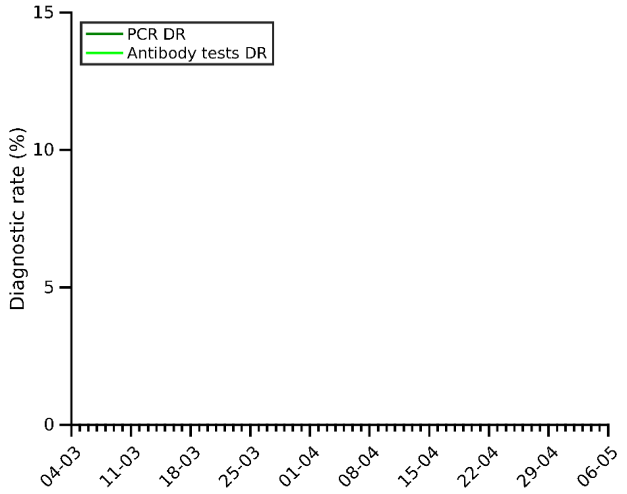


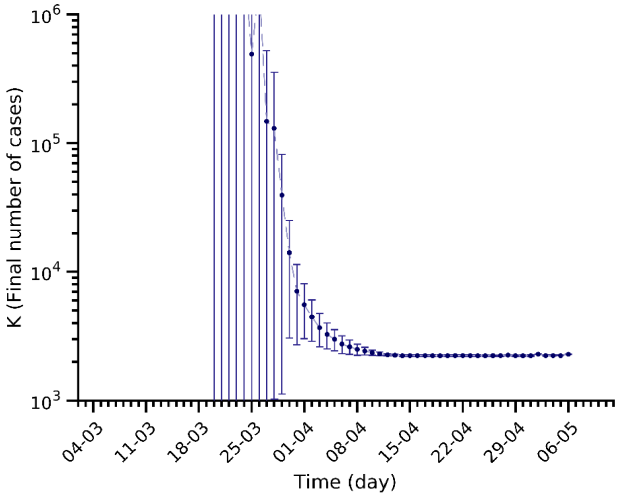


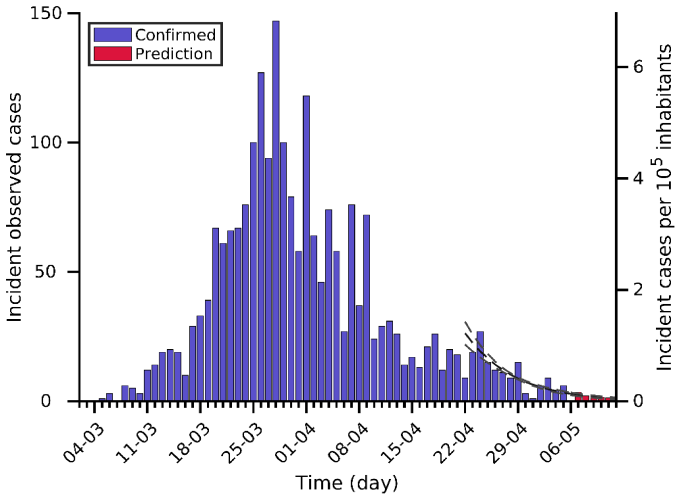
Canarias 06-05-2020. Population: 2.2M. Current cumulated incidence: 104/10⁵

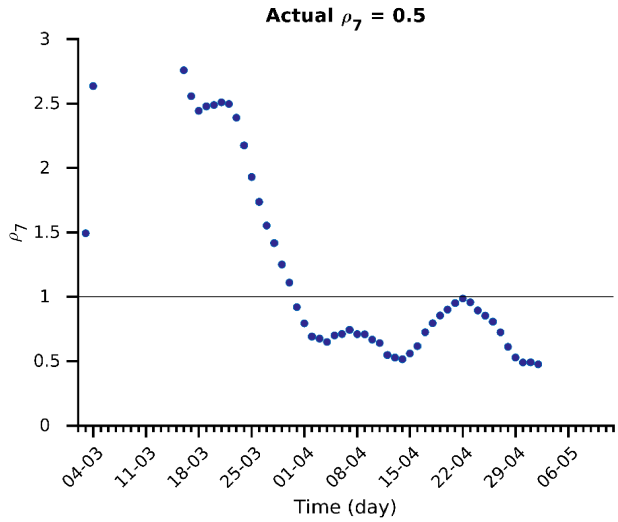


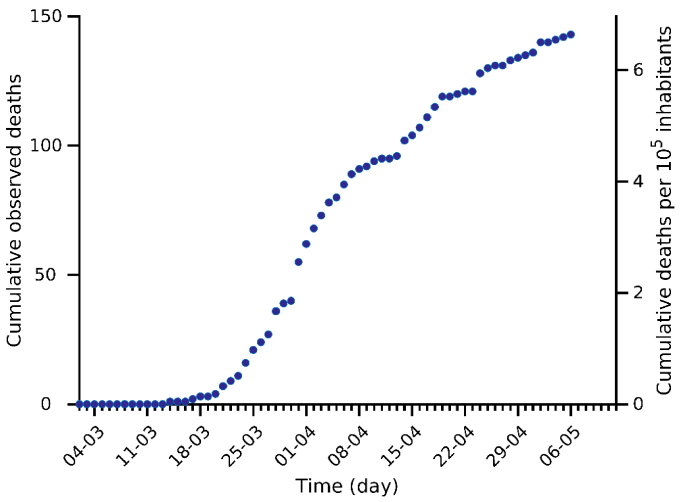


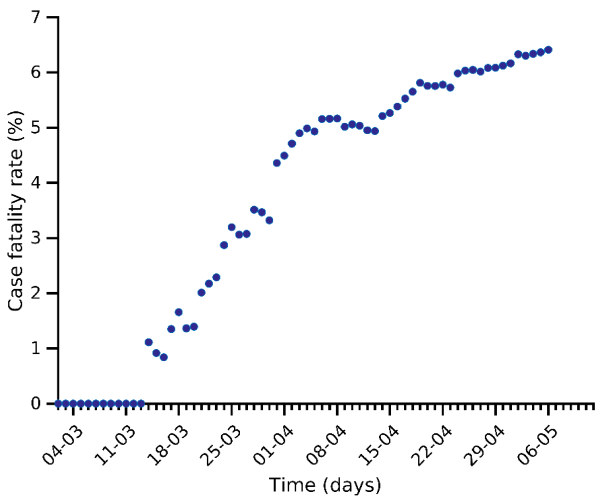




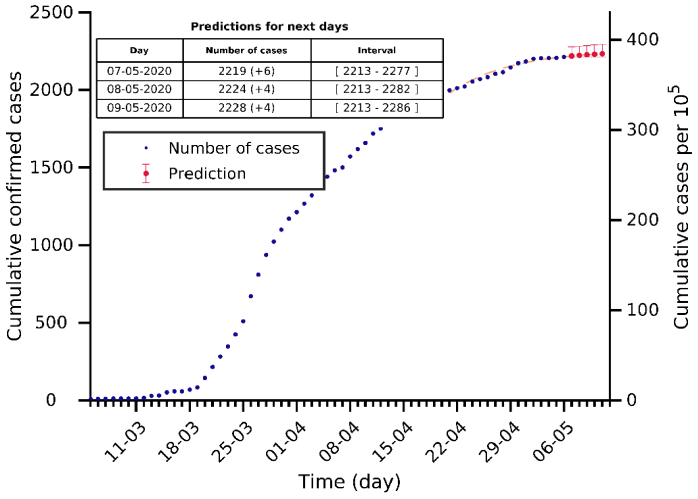


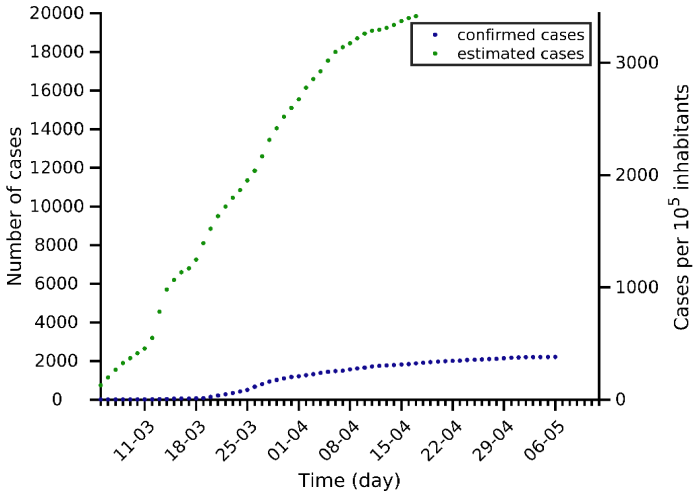


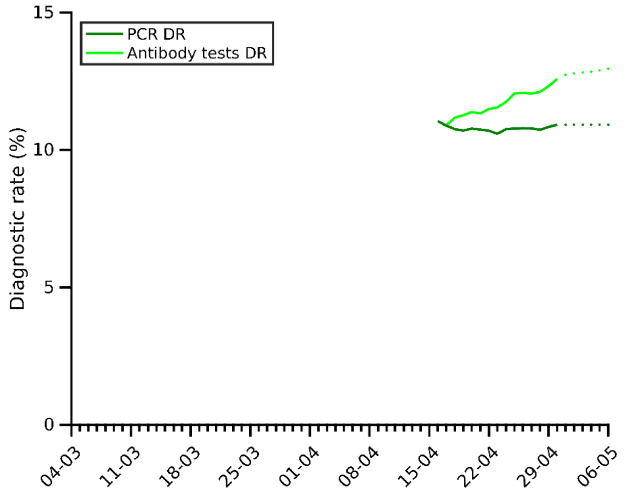


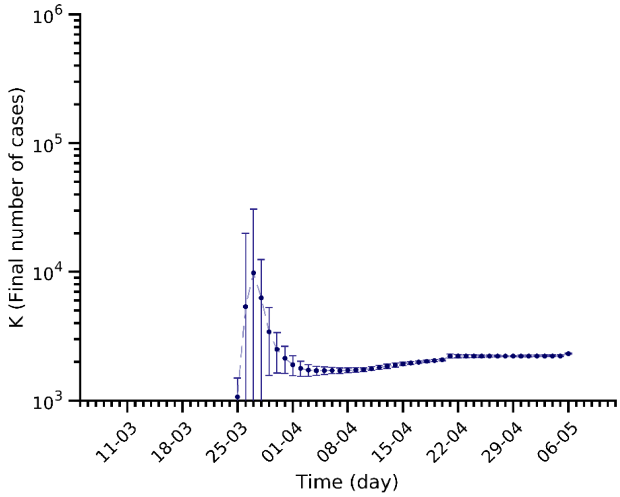


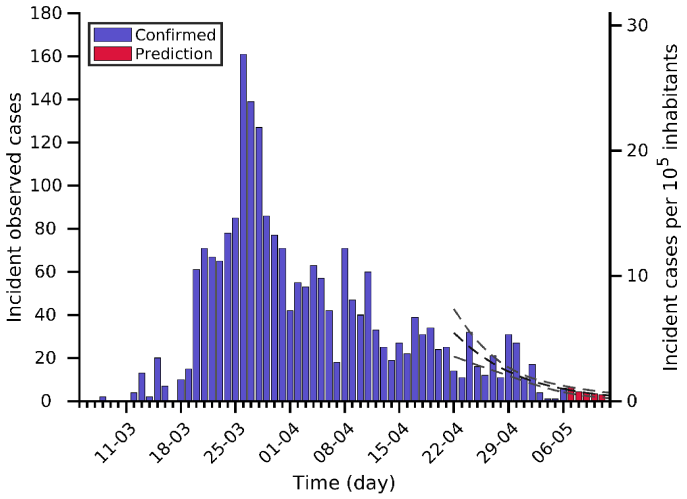
Cantabria 06-05-2020. Population: 0.6M. Current cumulated incidence: 381/10⁵

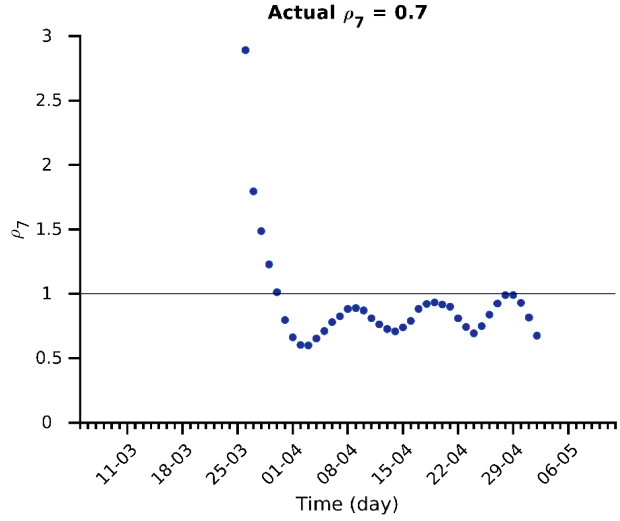


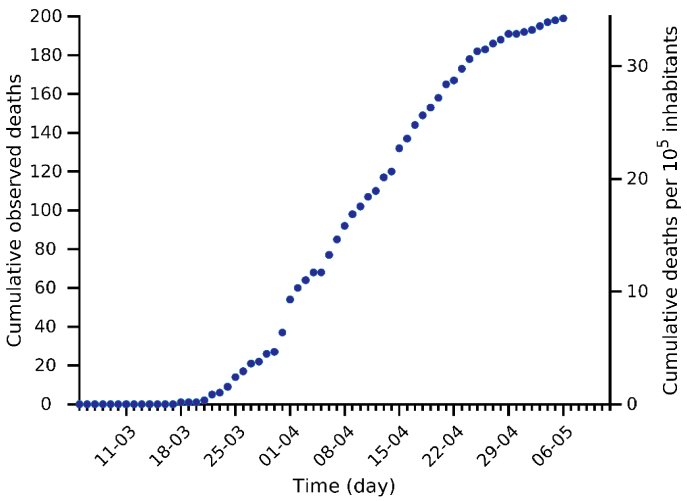


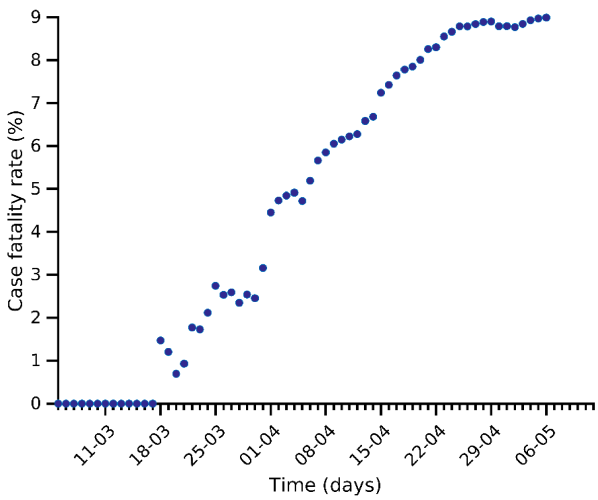




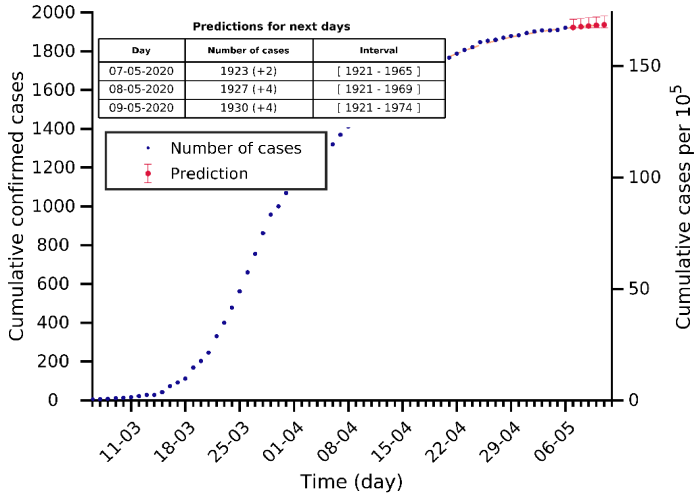


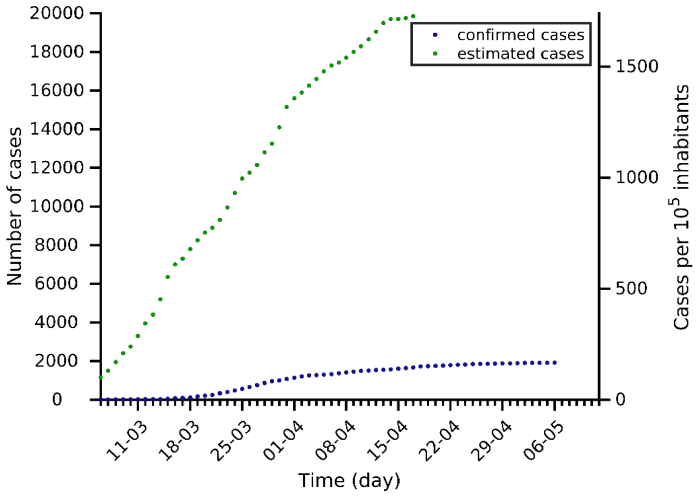


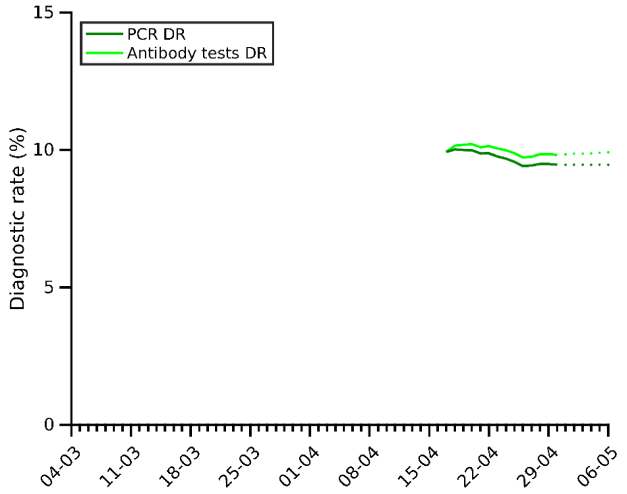


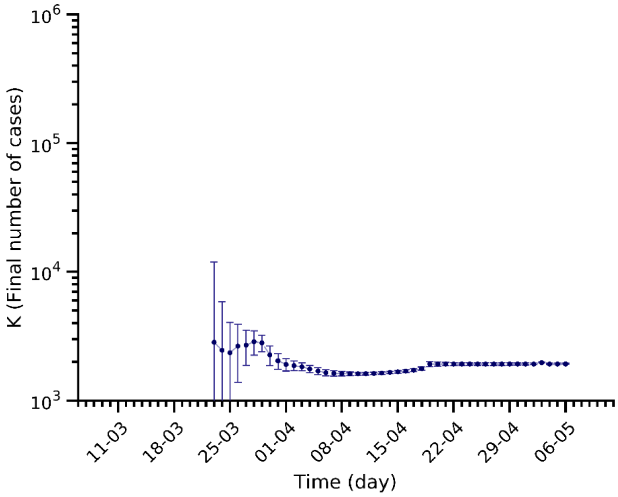


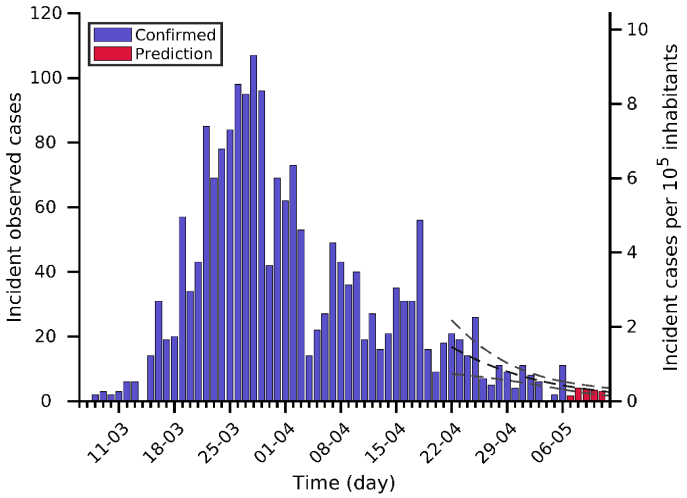
Baleares 06-05-2020. Population: 1.1M. Current cumulated incidence: 167/10^5

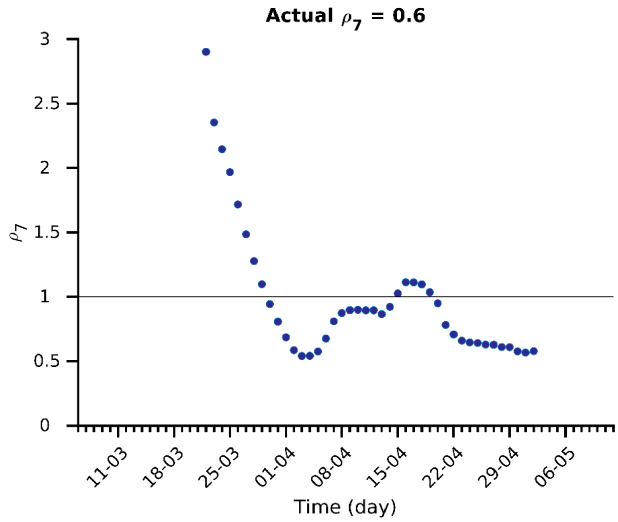


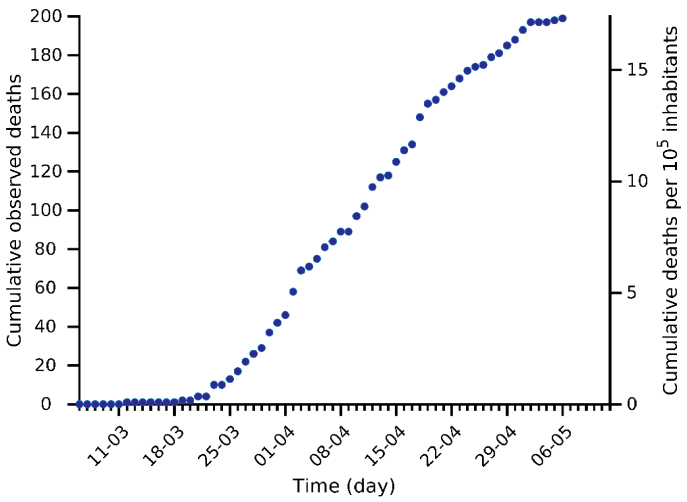


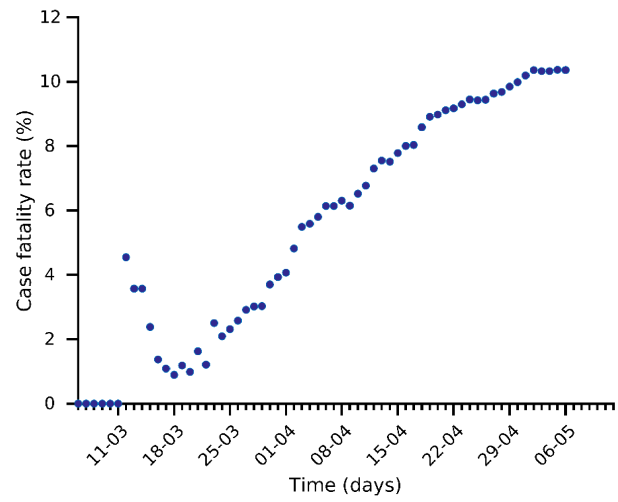




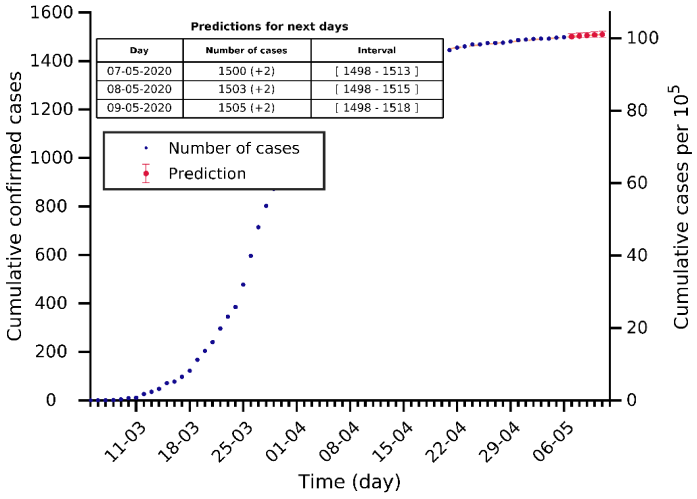


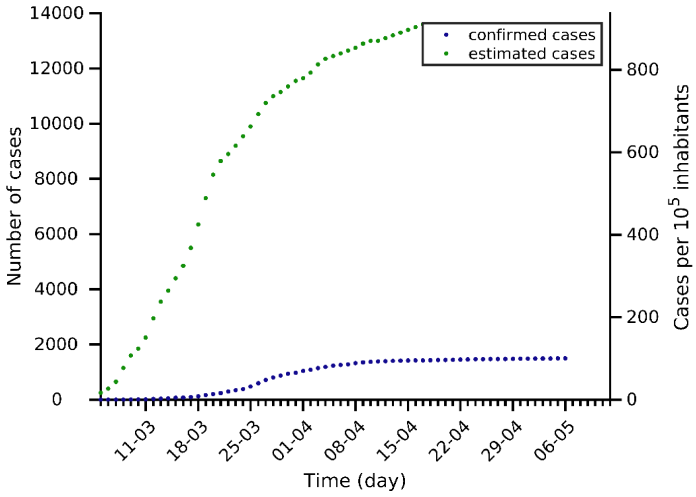


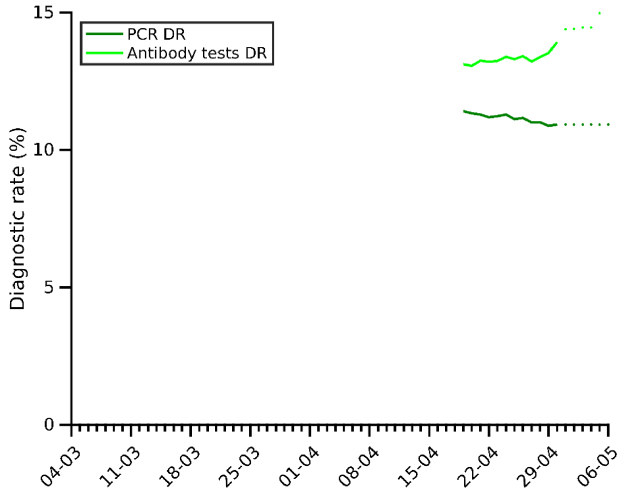


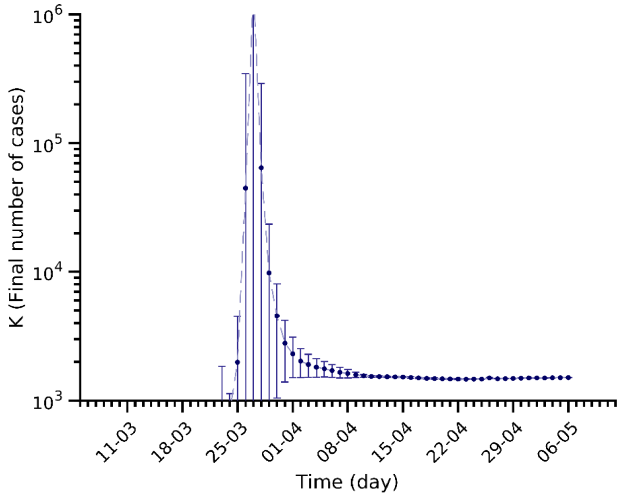


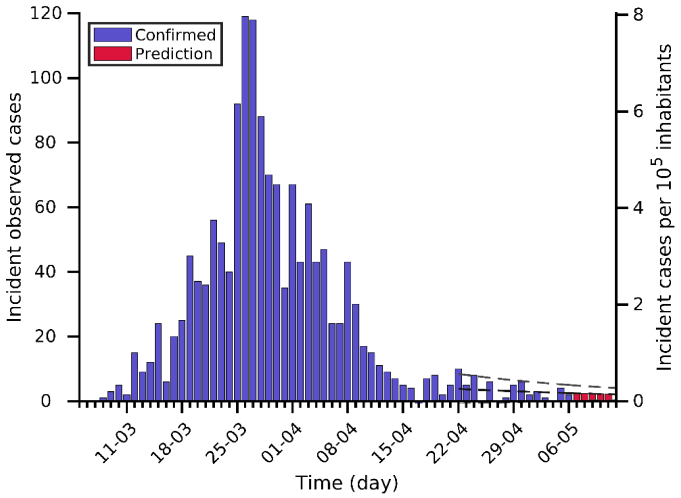
Murcia 06-05-2020. Population: 1.5M. Current cumulated incidence: 100/10^5

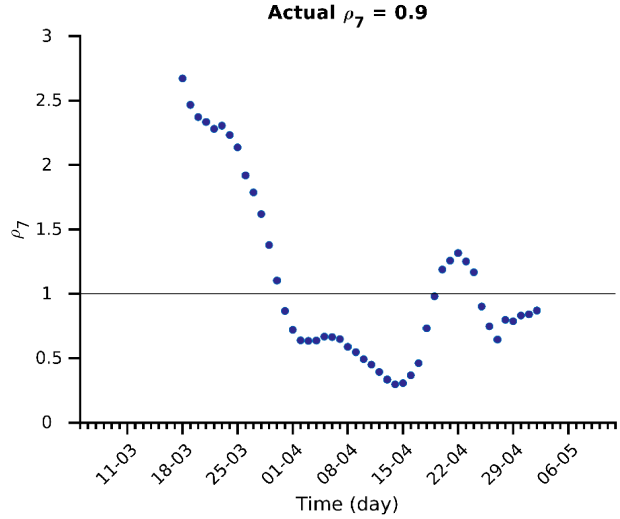


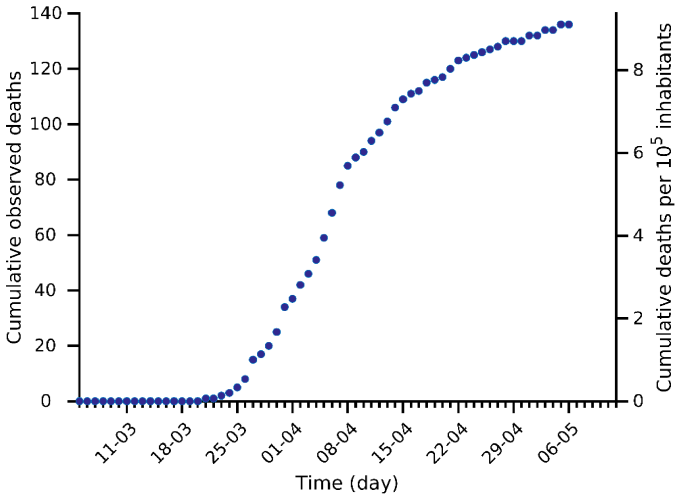


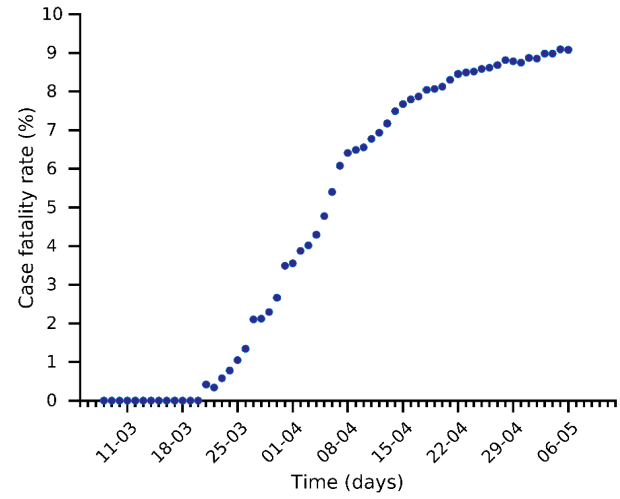








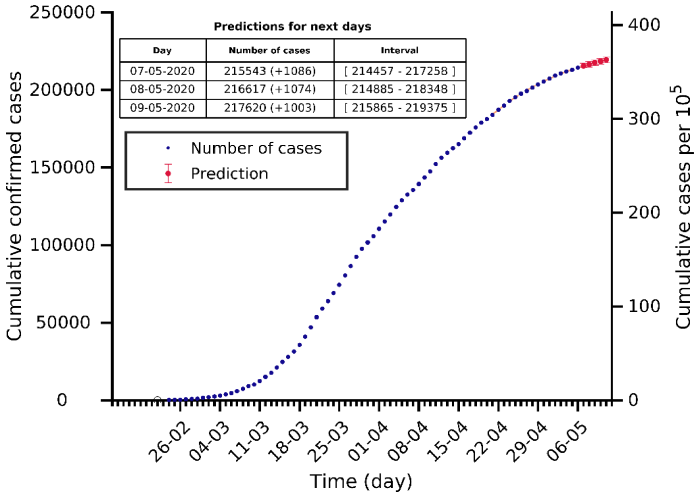


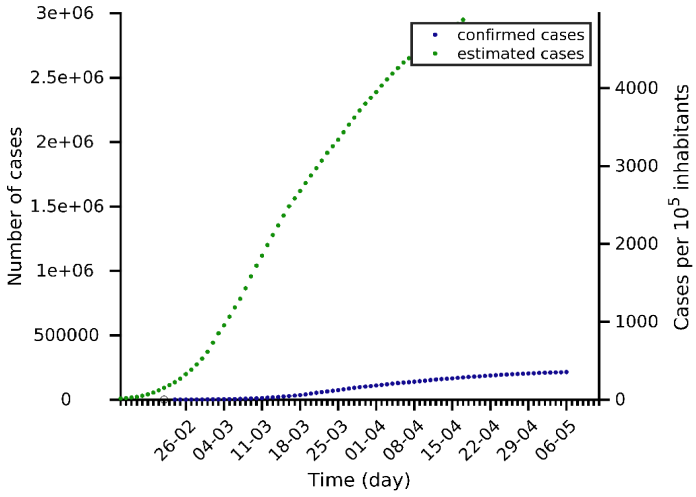


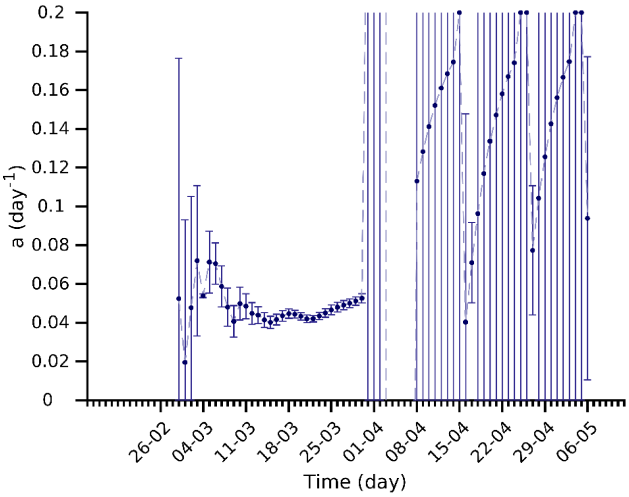
(4) Analysis and prediction of COVID-19 for Italy and its regions

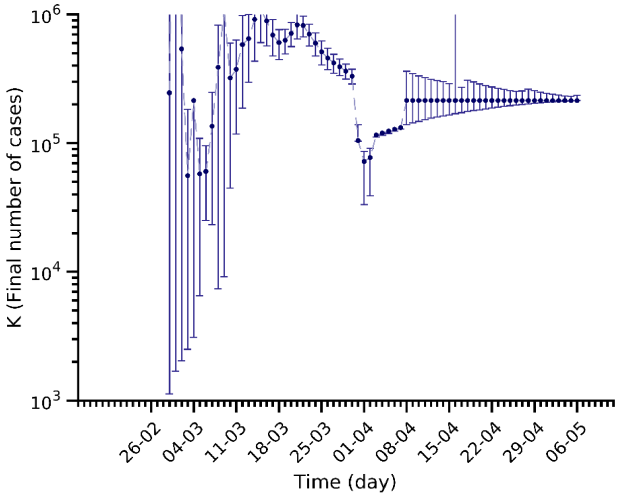
Data obtained from: https://github.com/pcm-dpc/COVID-19/tree/master/dati-andamento-nazionale

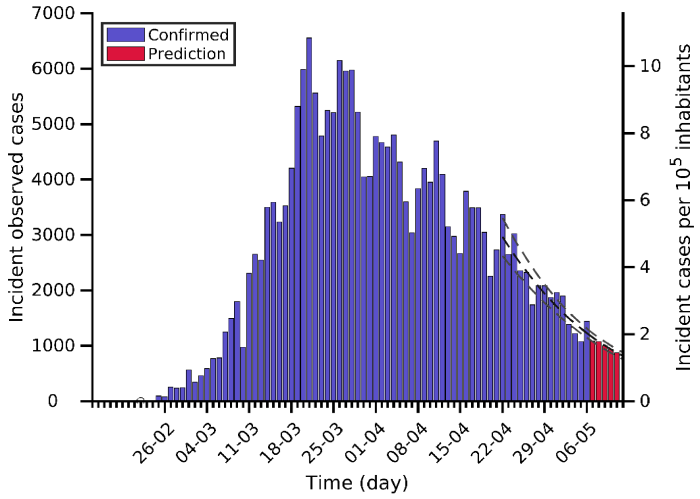
Italy 06-05-2020. Population: 60.5M. Current cumulated incidence: 355/10^5

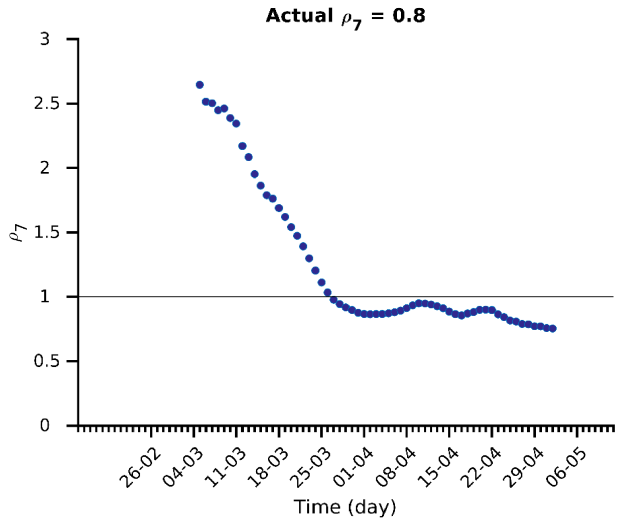


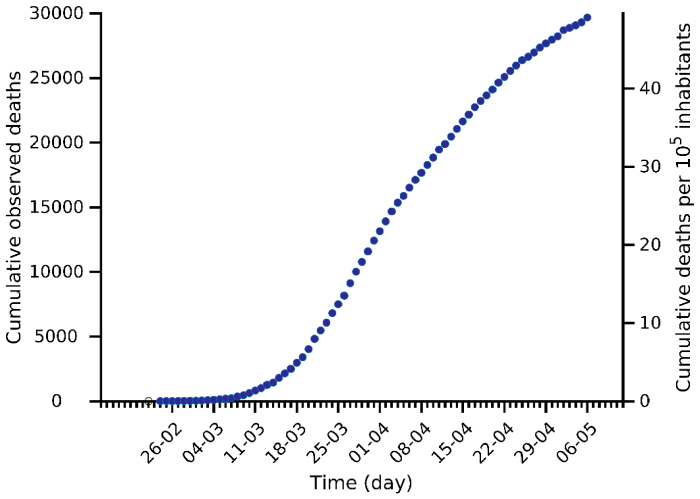


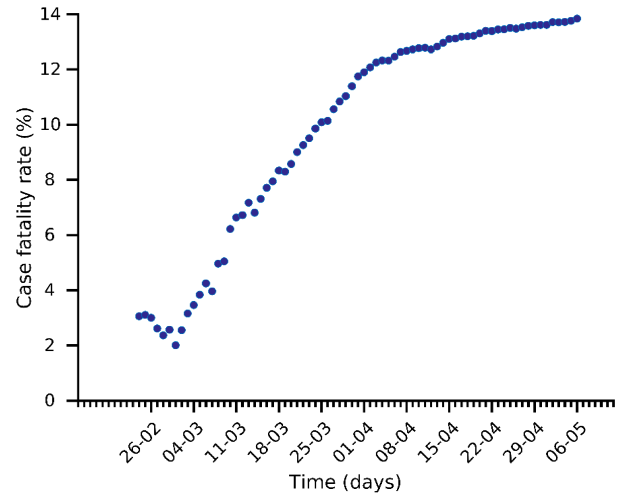




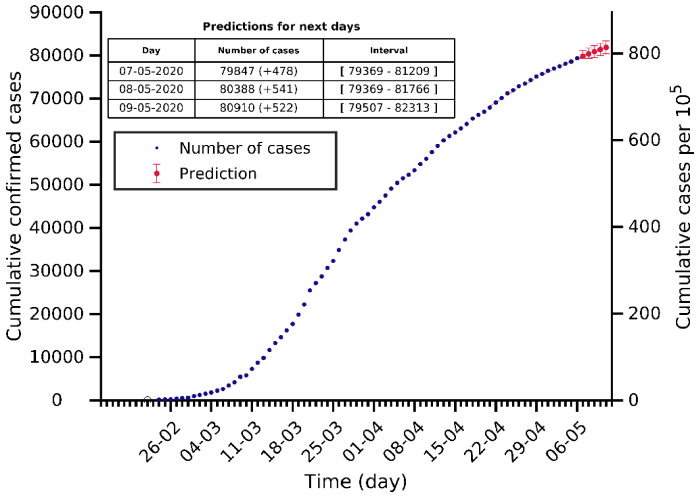


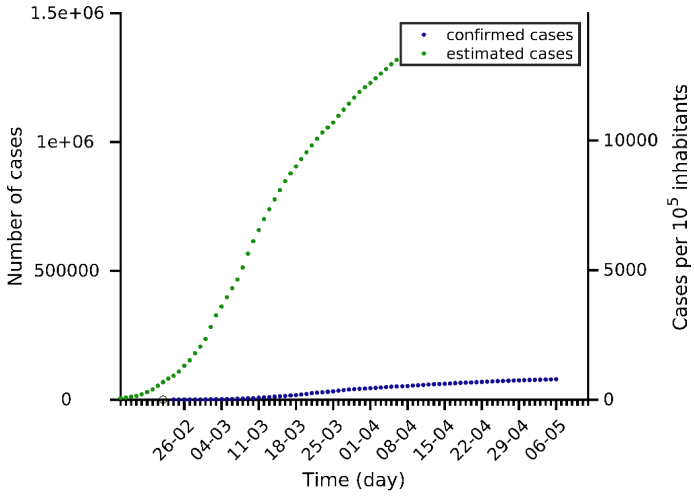


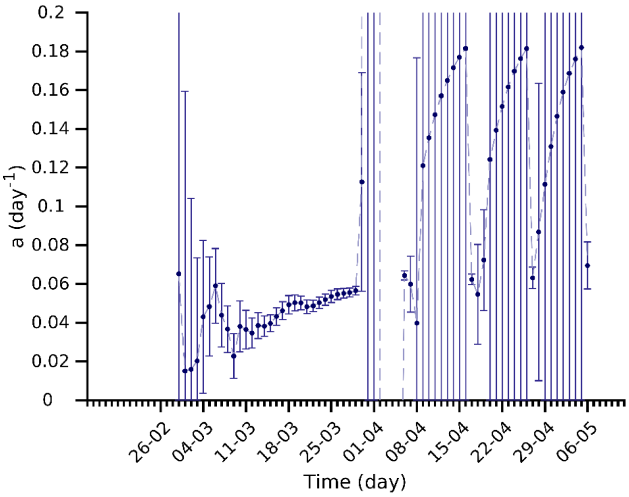


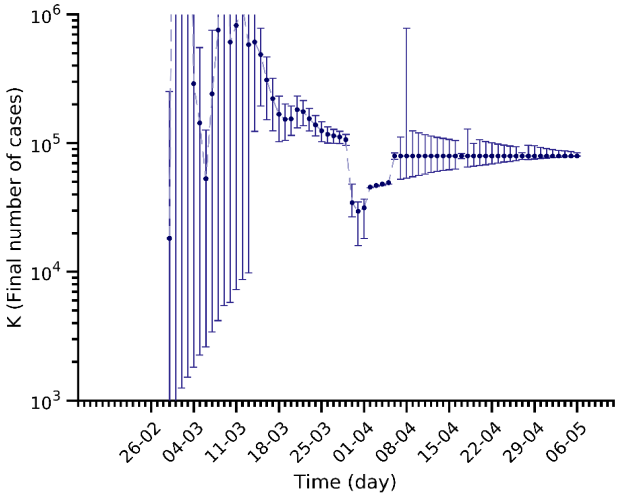


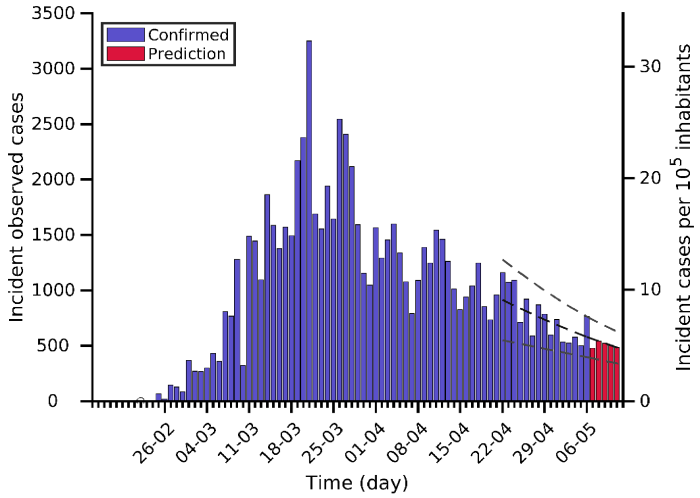
Lombardia 06-05-2020. Population: 10.1M. Current cumulated incidence: 789/10^5

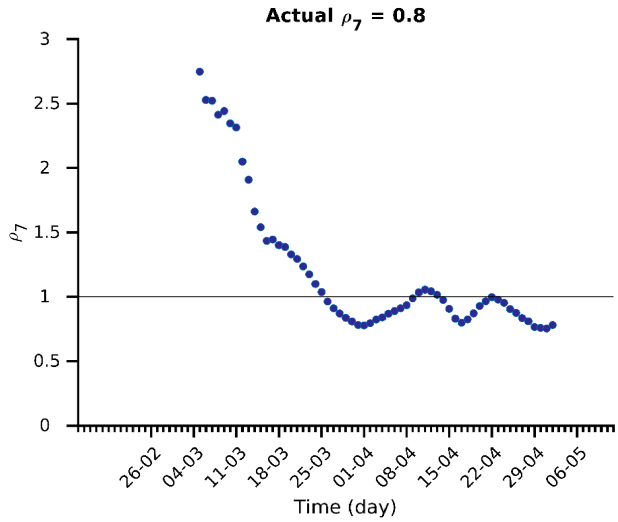


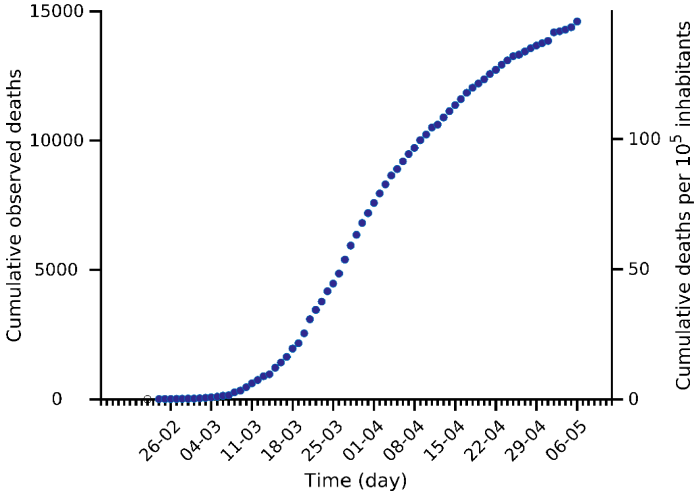


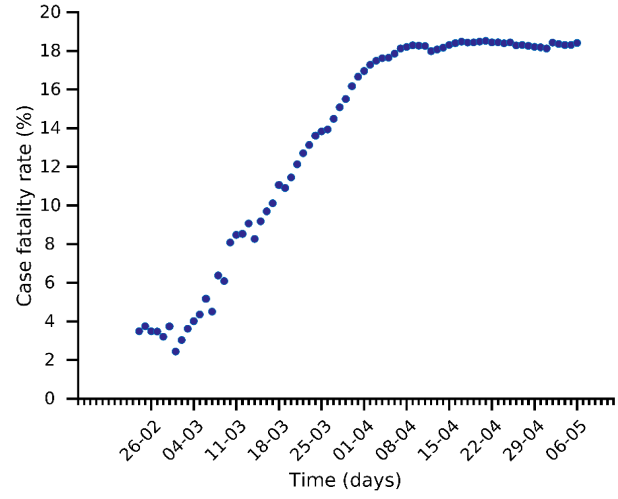




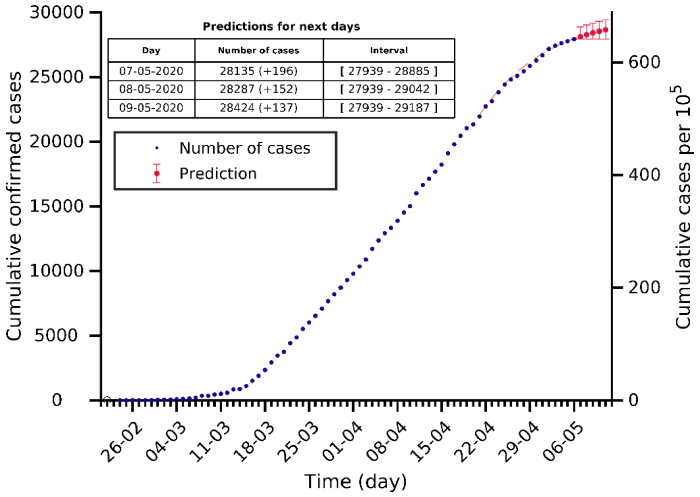


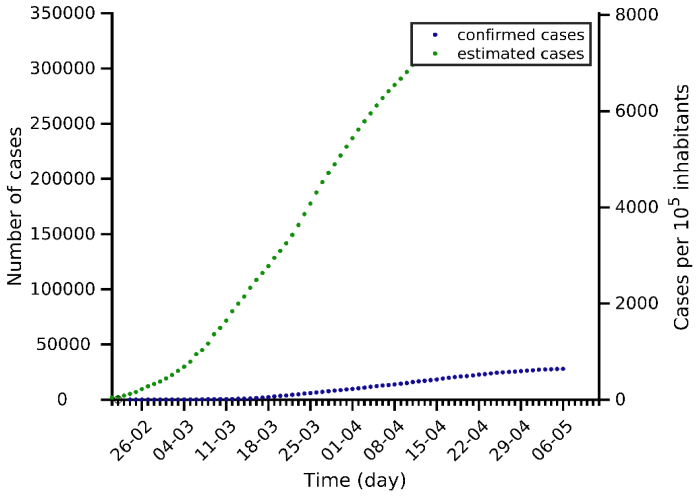


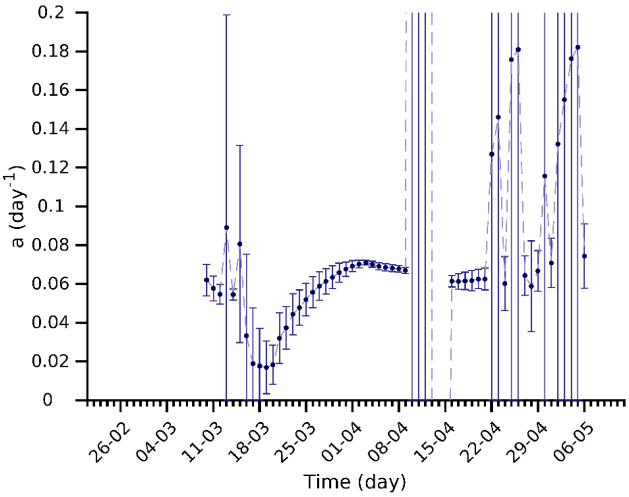


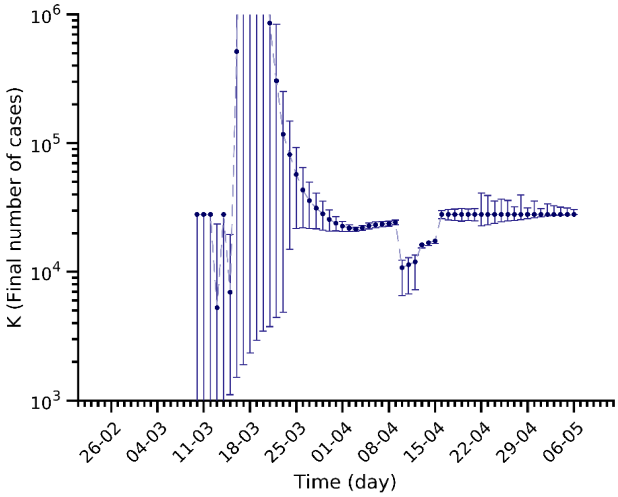


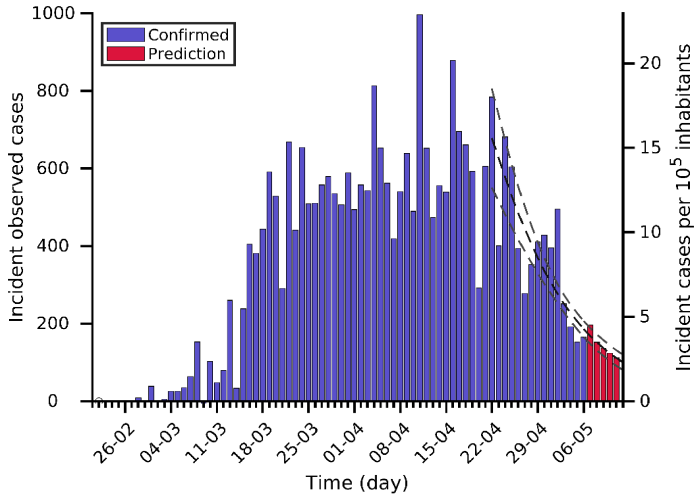
Piemonte 06-05-2020. Population: 4.4M. Current cumulated incidence: 641/10⁵

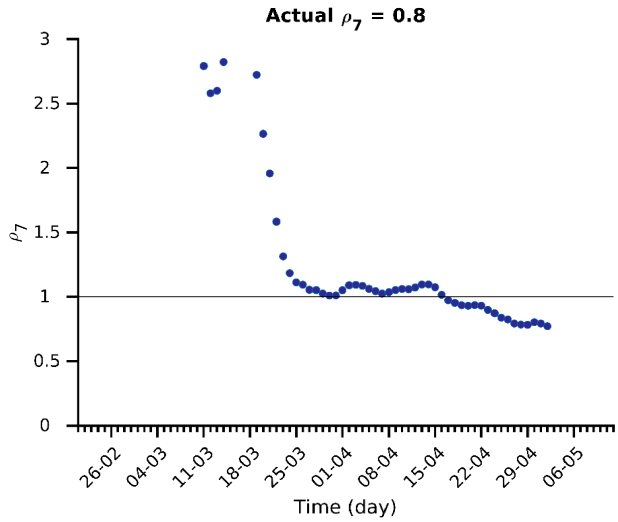


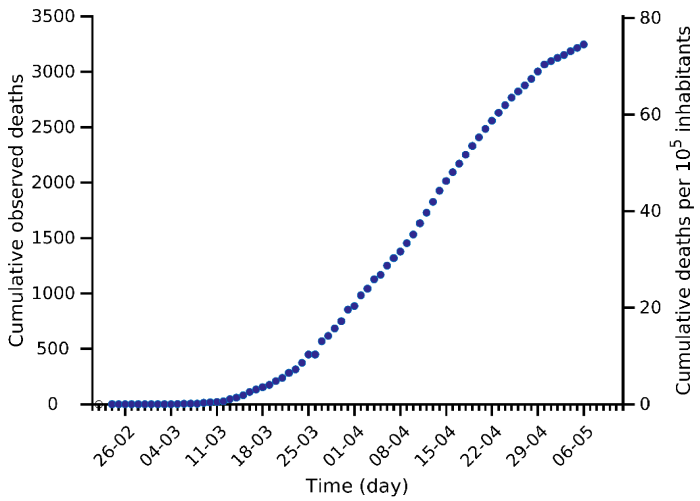


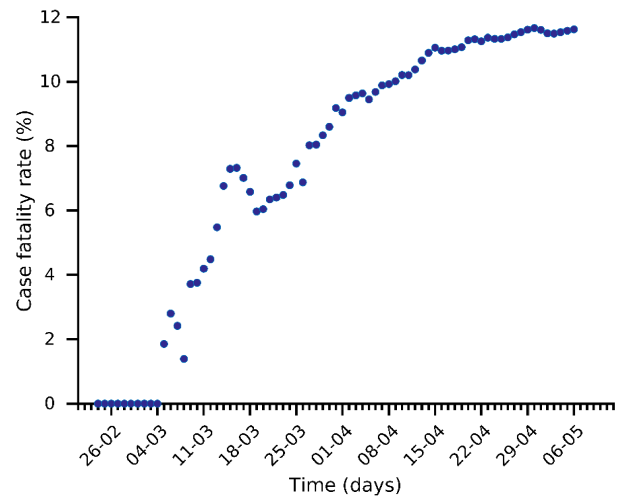




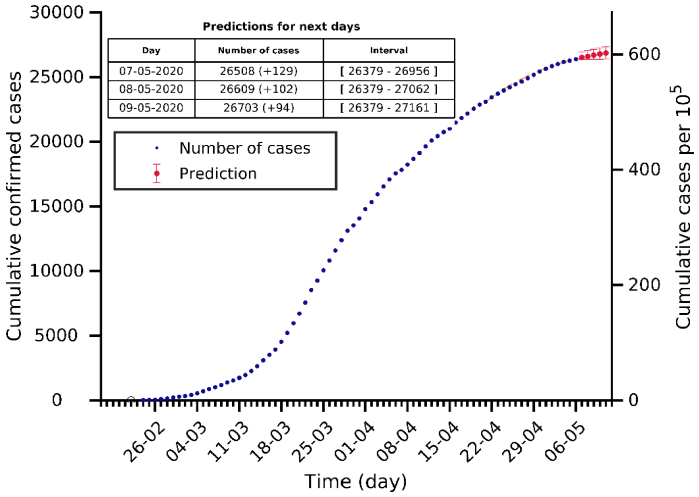


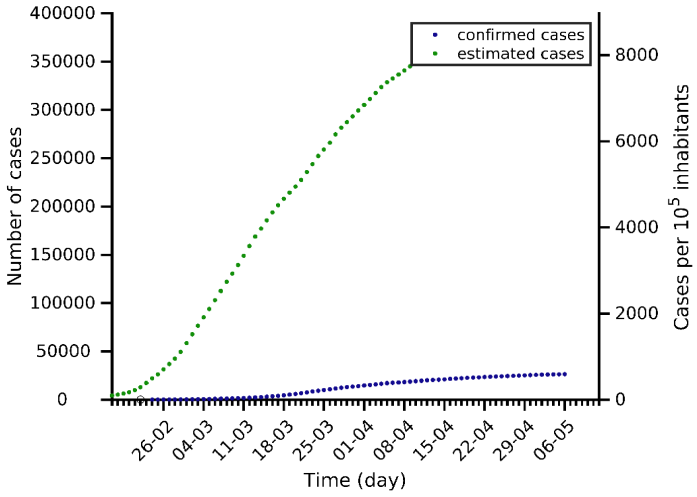


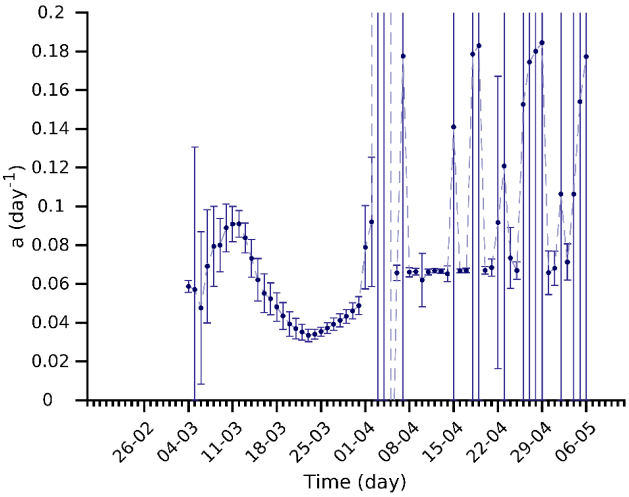


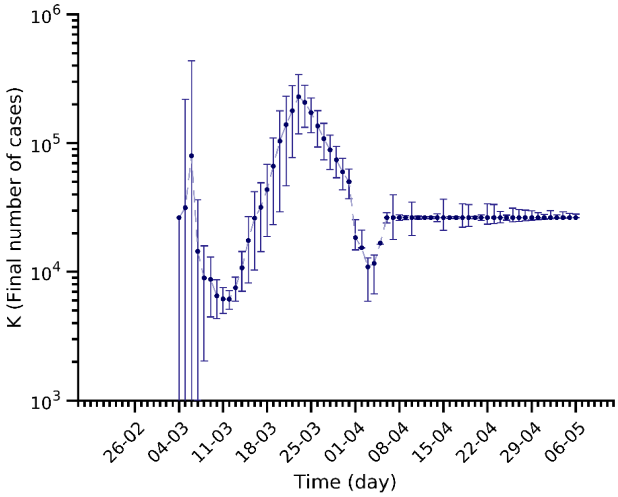


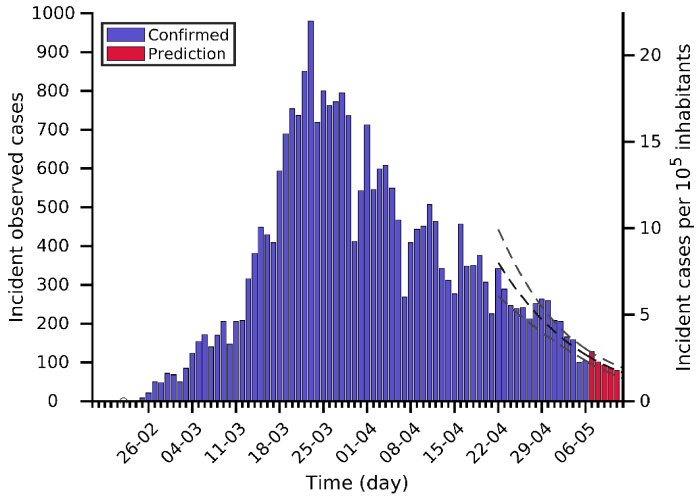
Emilia Romagna 06-05-2020. Population: 4.5M. Current cumulated incidence: 592/1

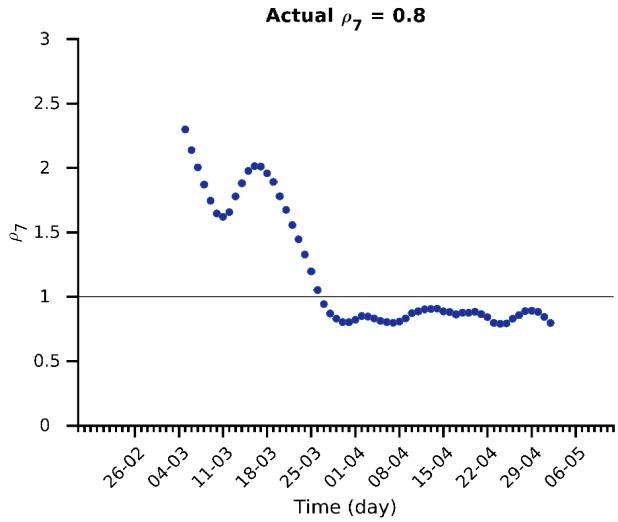


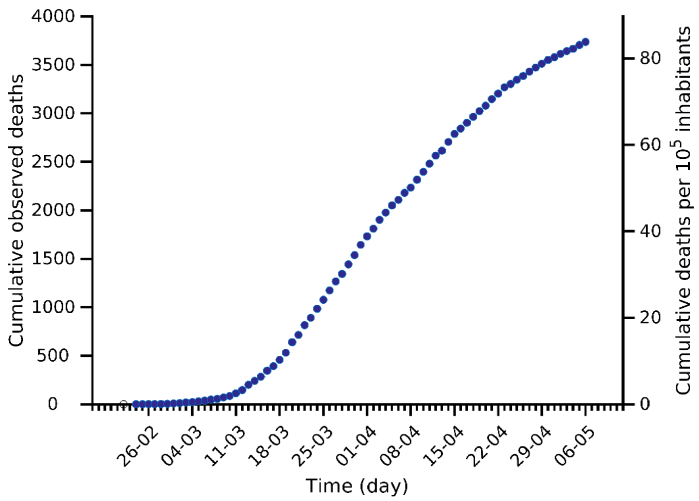


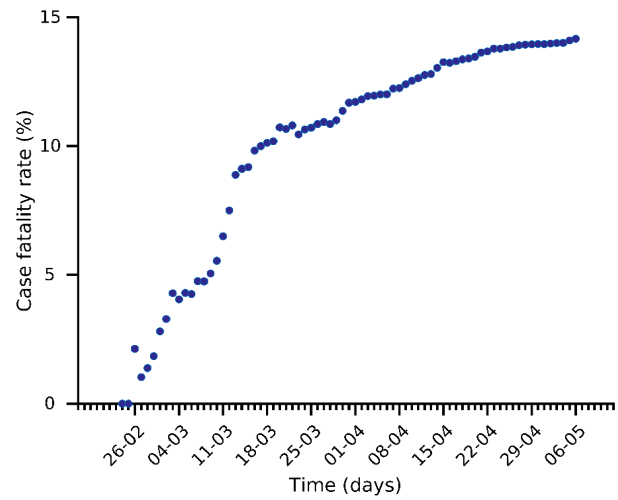




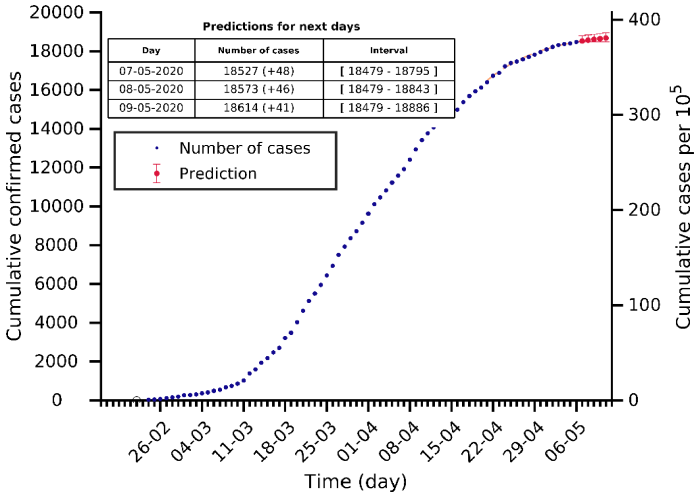


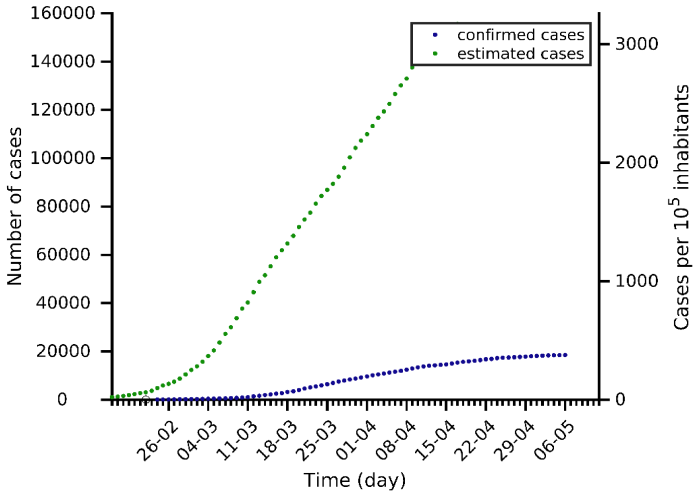


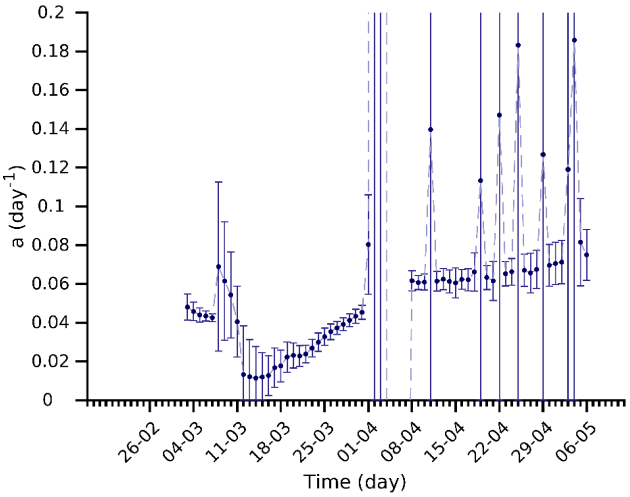


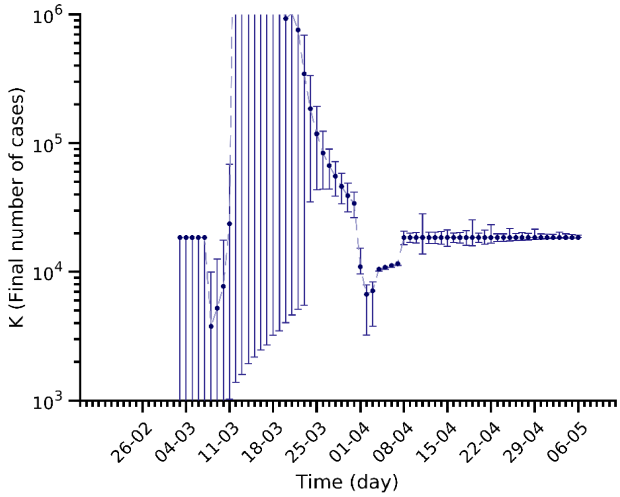


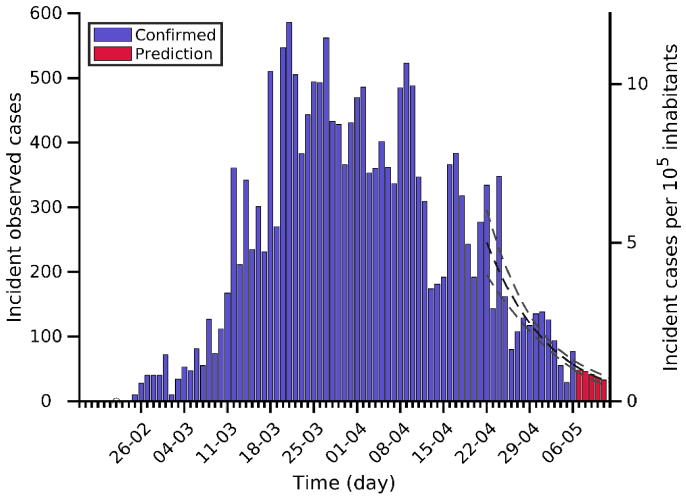
Veneto 06-05-2020. Population: 4.9M. Current cumulated incidence: 377/10⁵

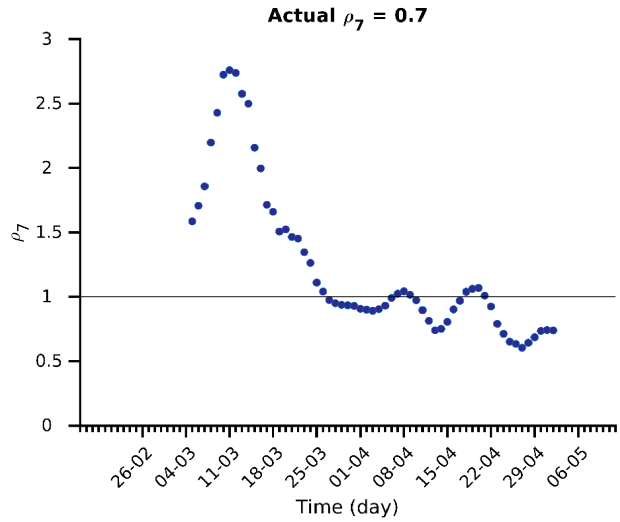


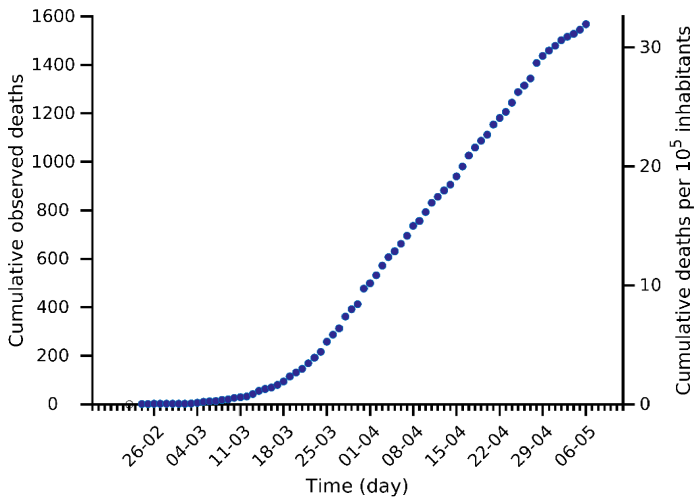


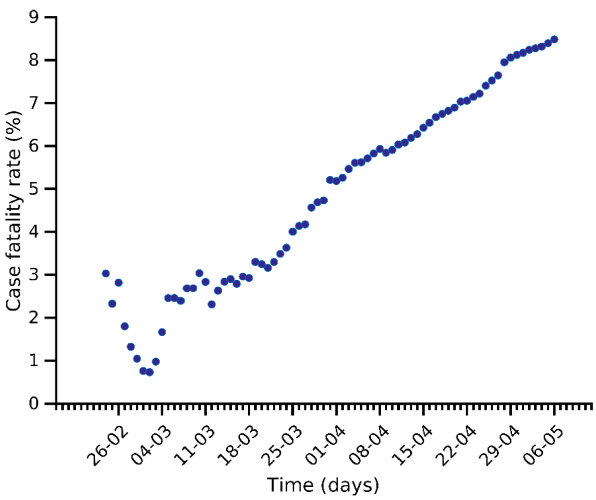




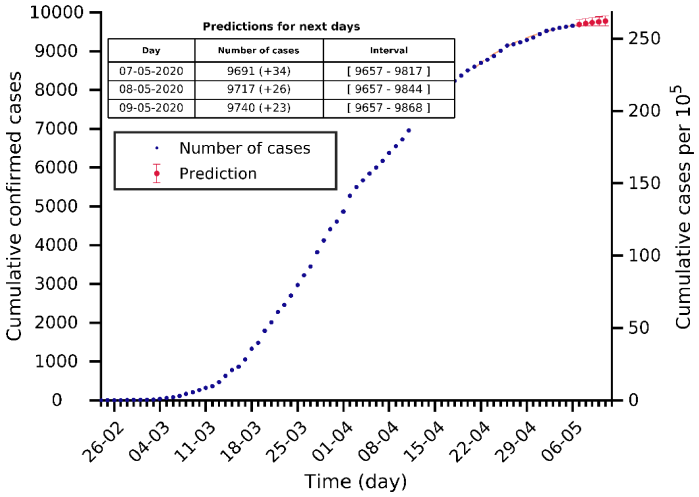


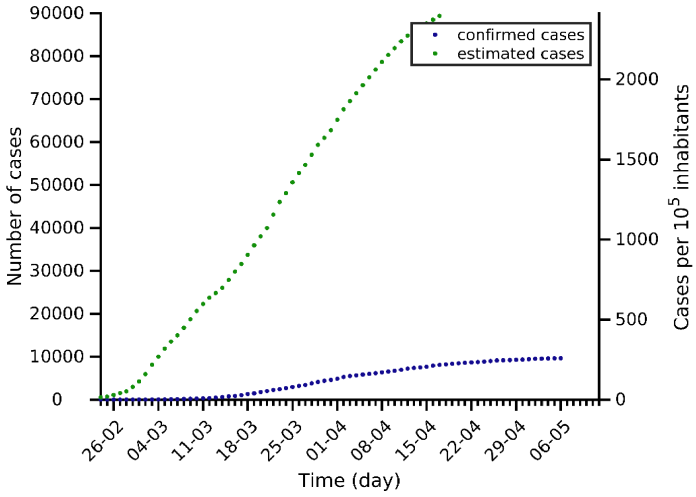


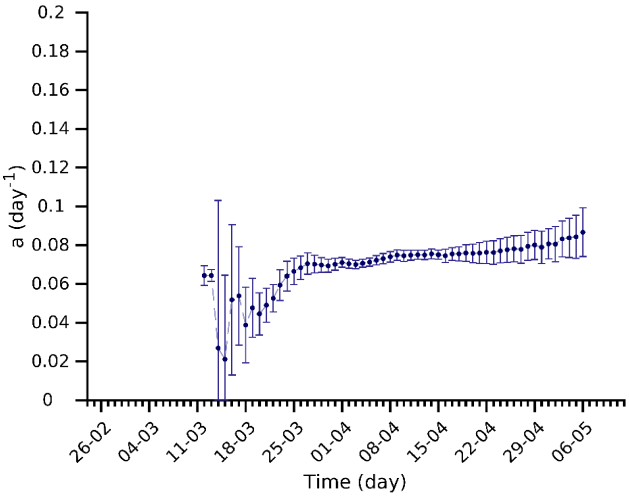


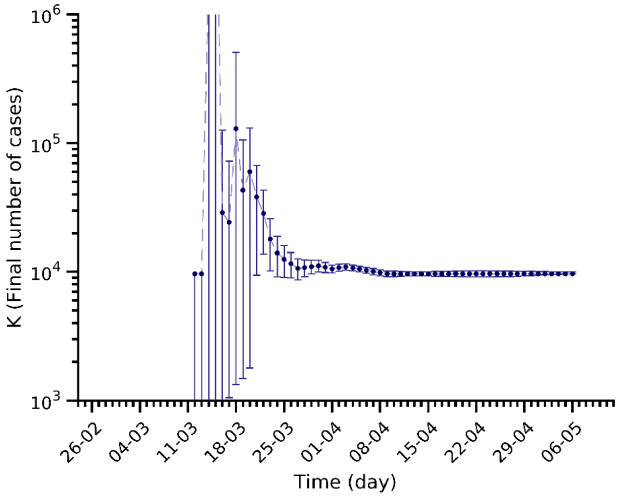


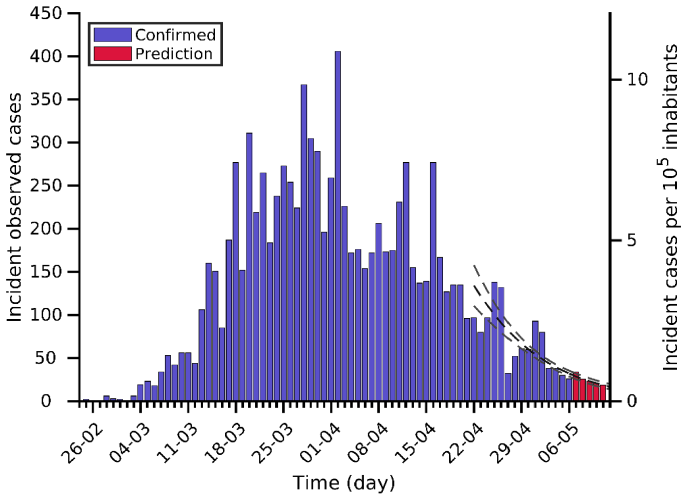
Toscana 06-05-2020. Population: 3.7M. Current cumulated incidence: 259/10⁵

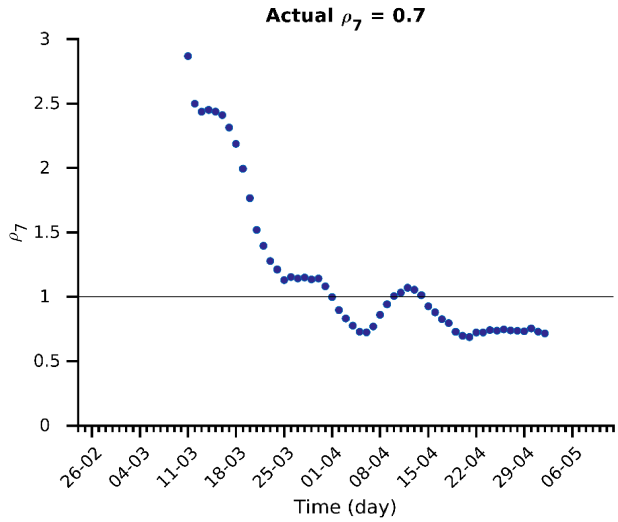


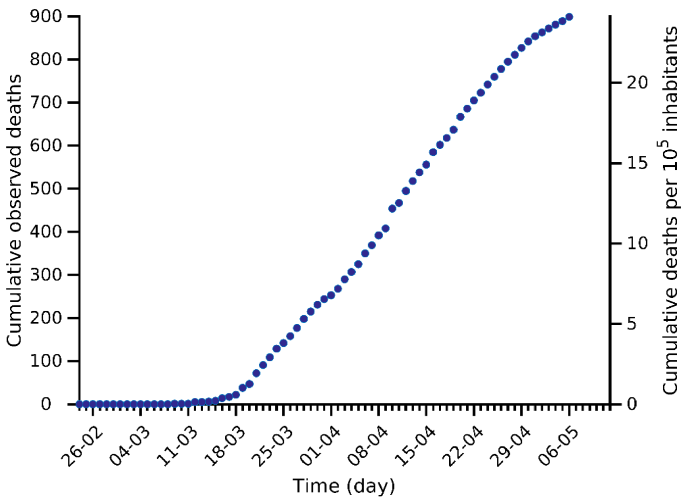


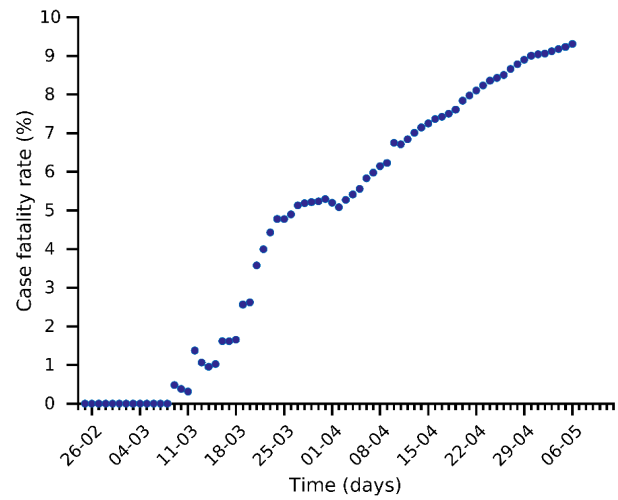




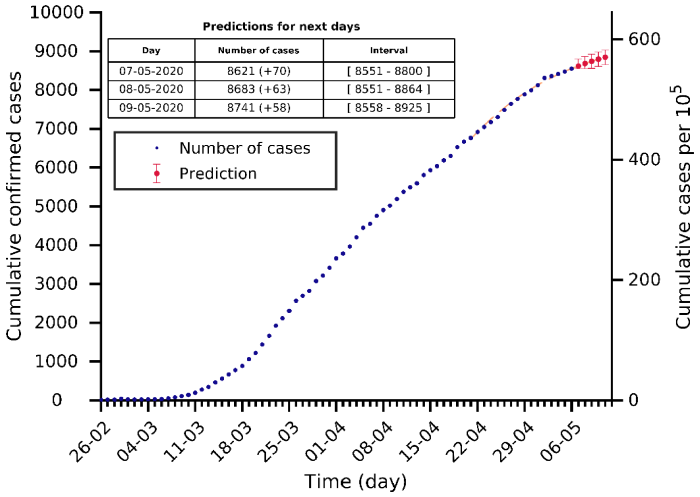


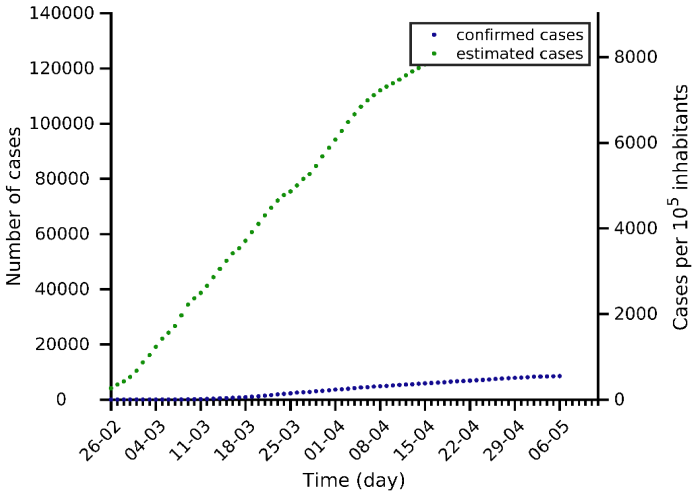


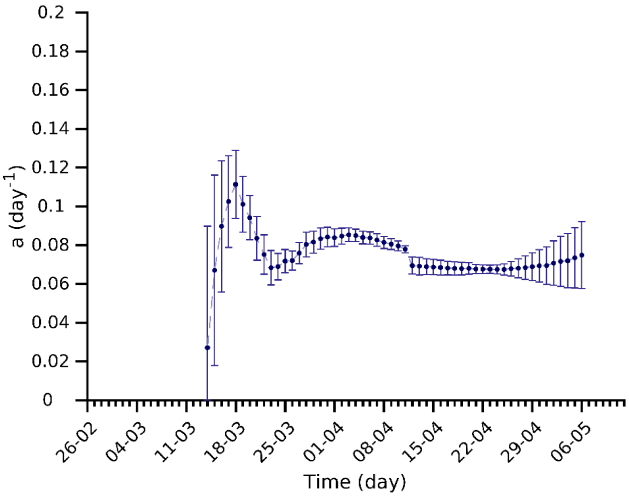


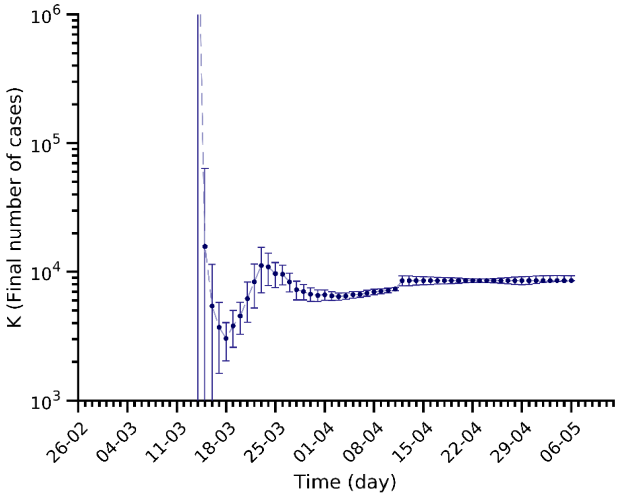


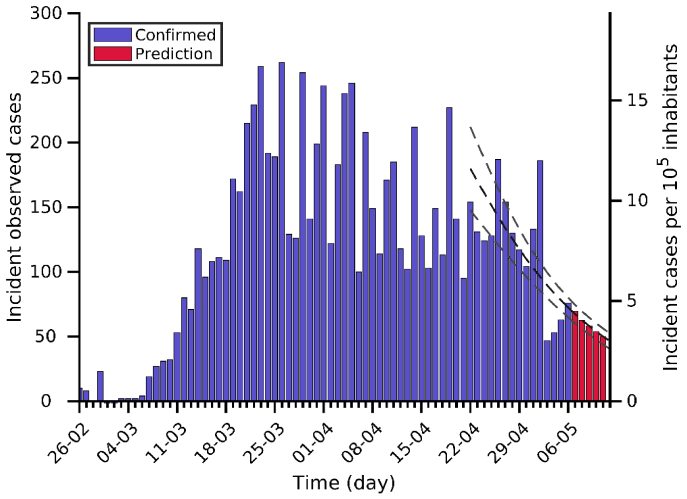
Liguria 06-05-2020. Population: 1.6M. Current cumulated incidence: 551/10^5

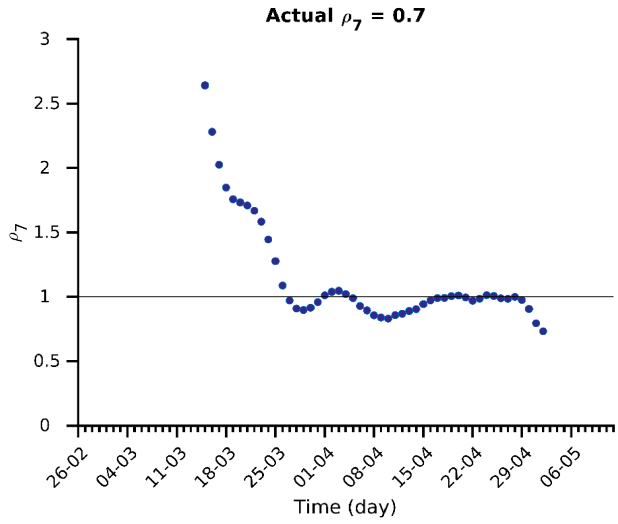


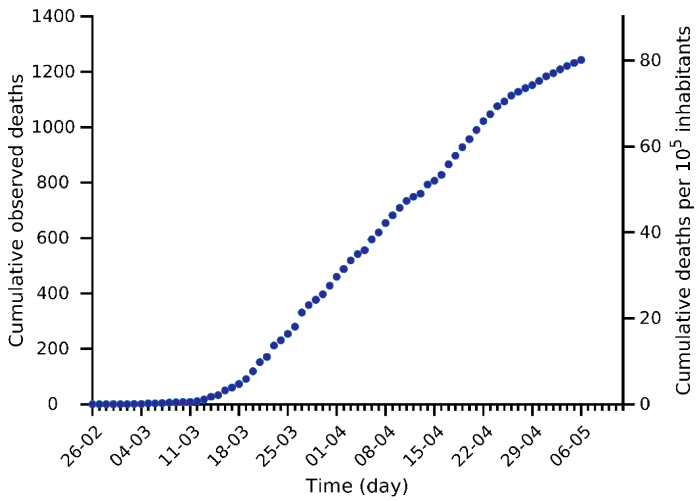


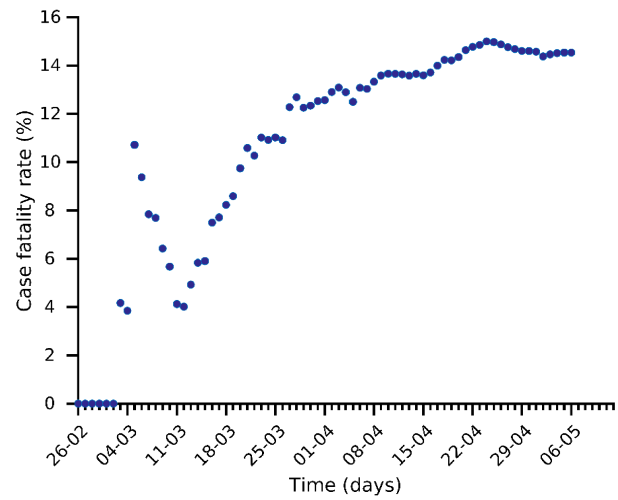




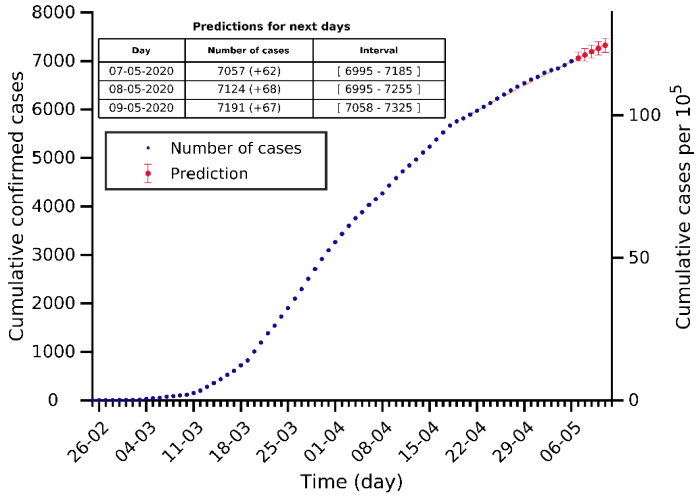


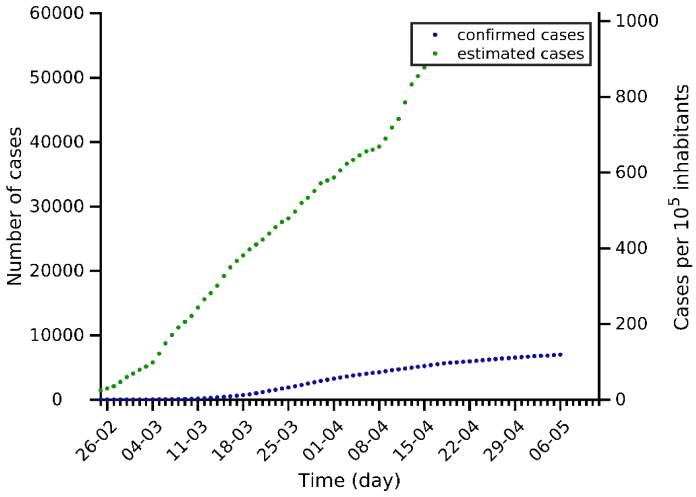


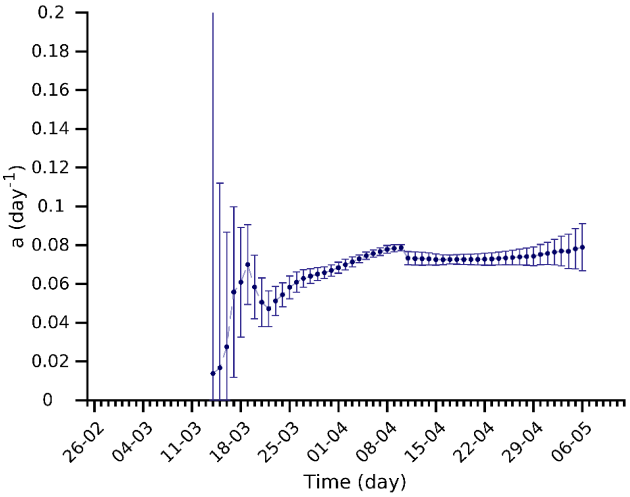


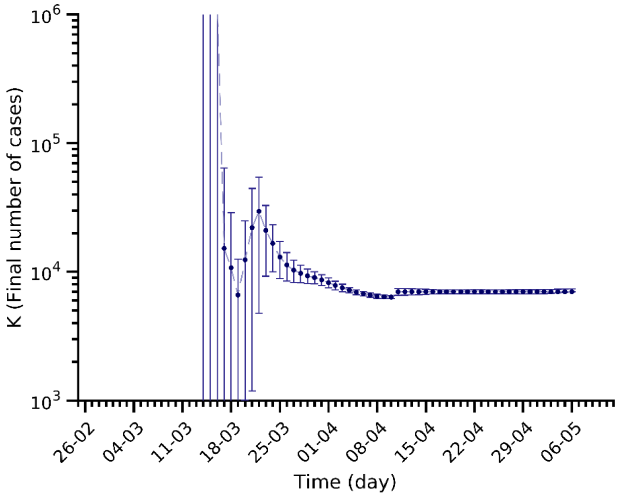


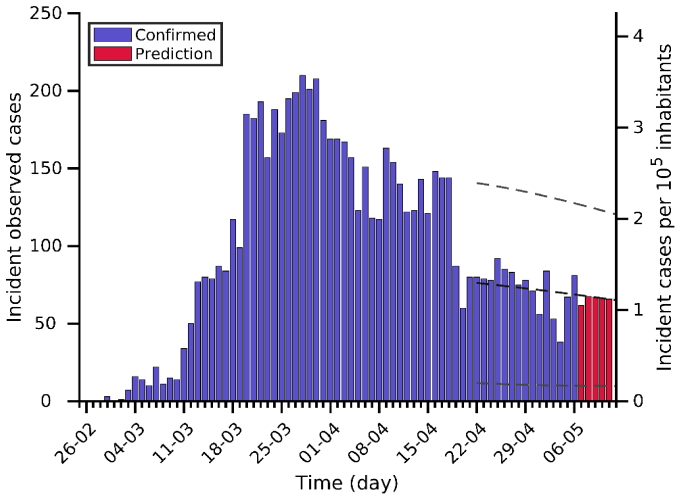
Lazio 06-05-2020. Population: 5.9M. Current cumulated incidence: 119/10⁵

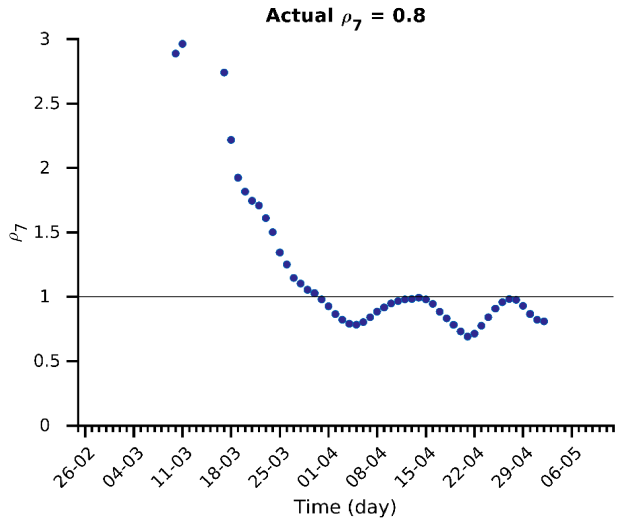


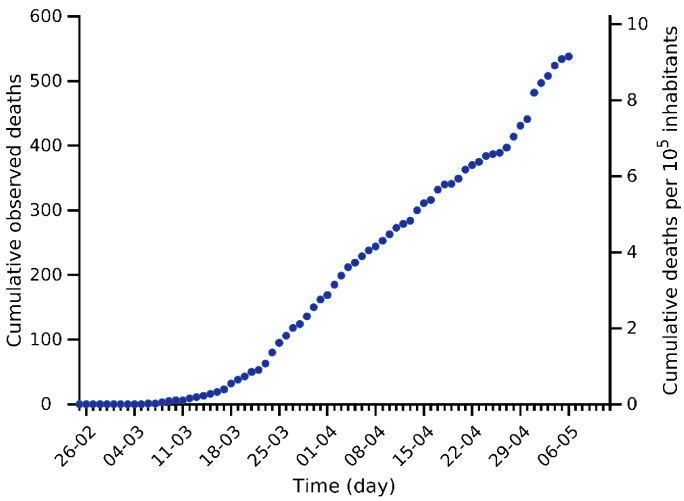


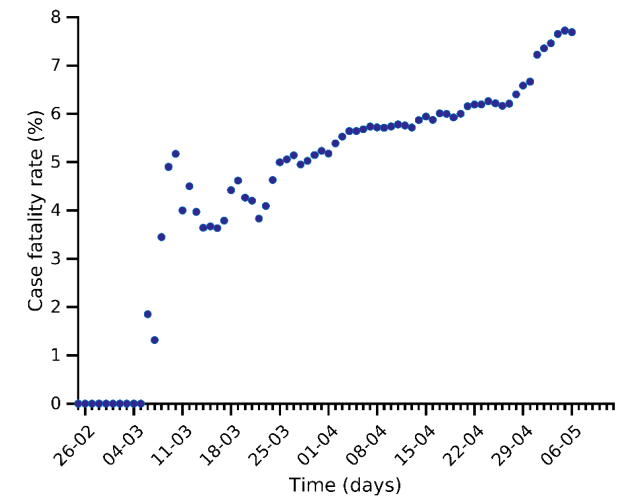




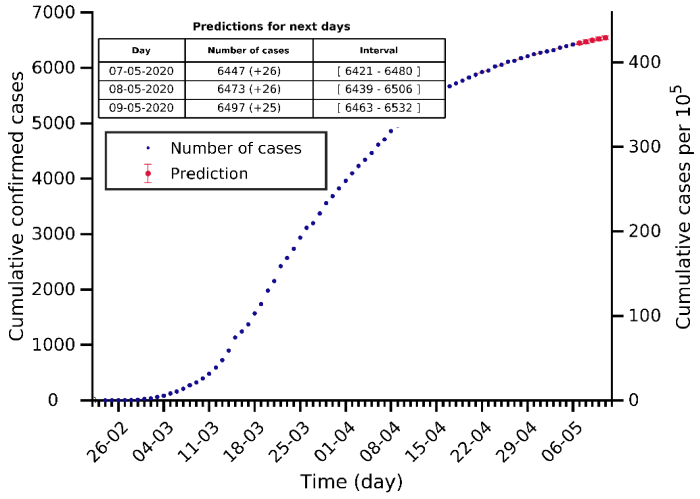


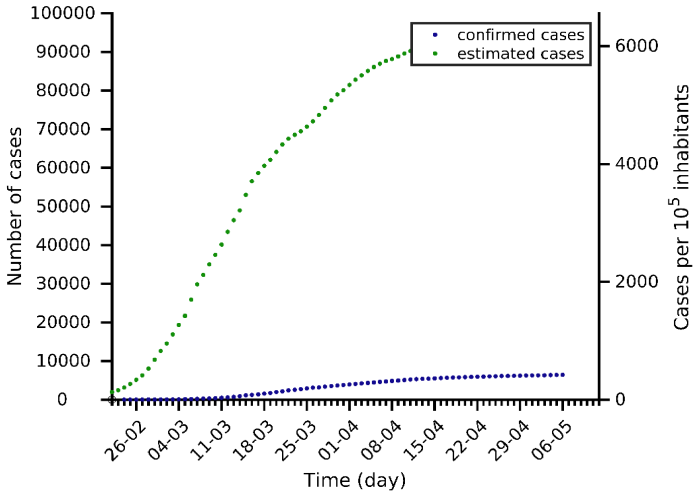


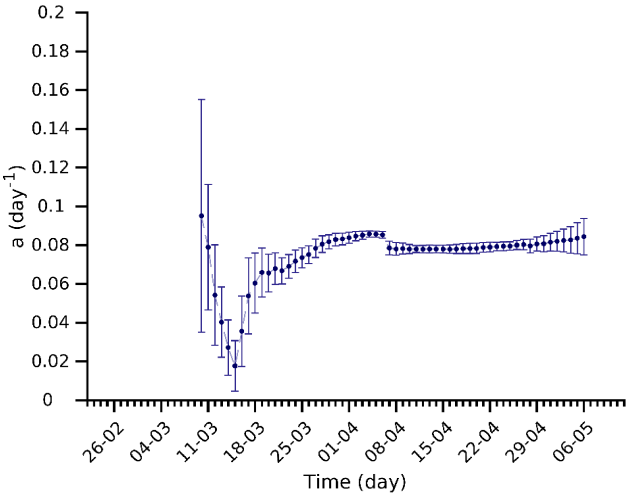


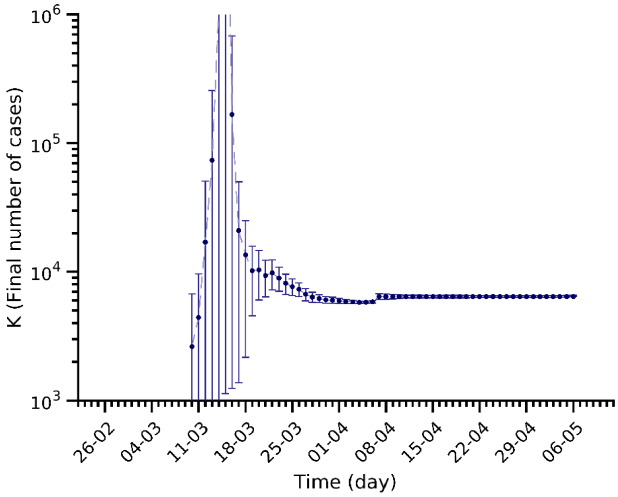


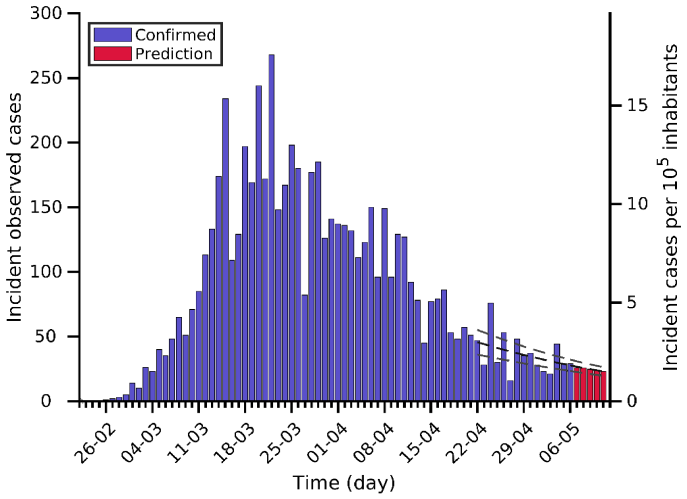
Marche 06-05-2020. Population: 1.5M. Current cumulated incidence: 421/10^5

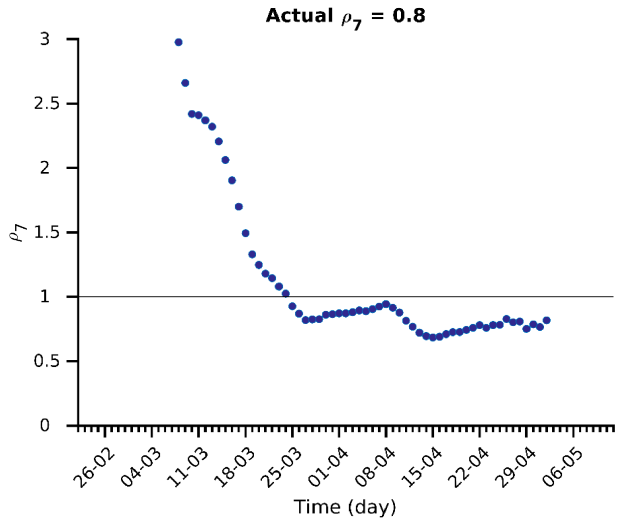


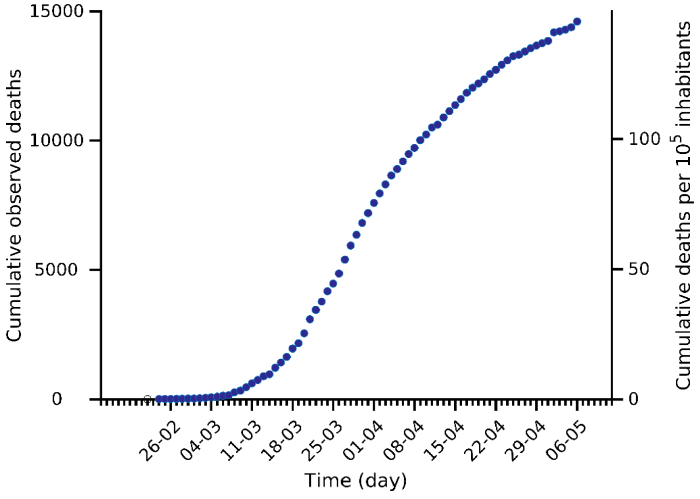


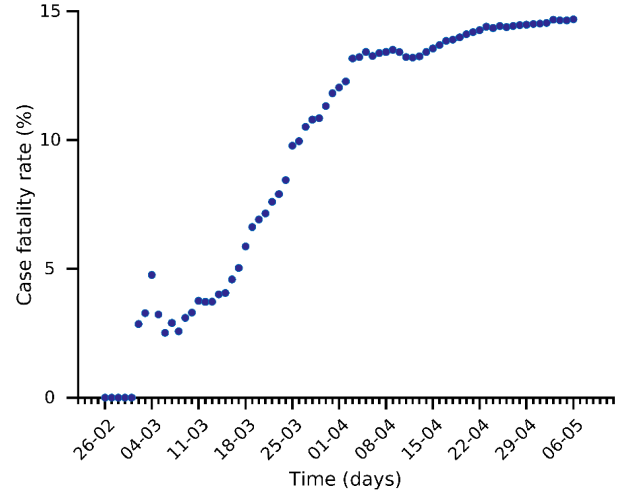




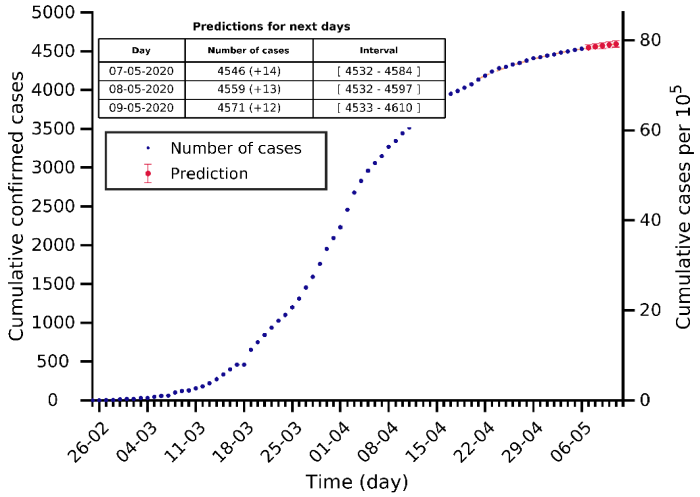


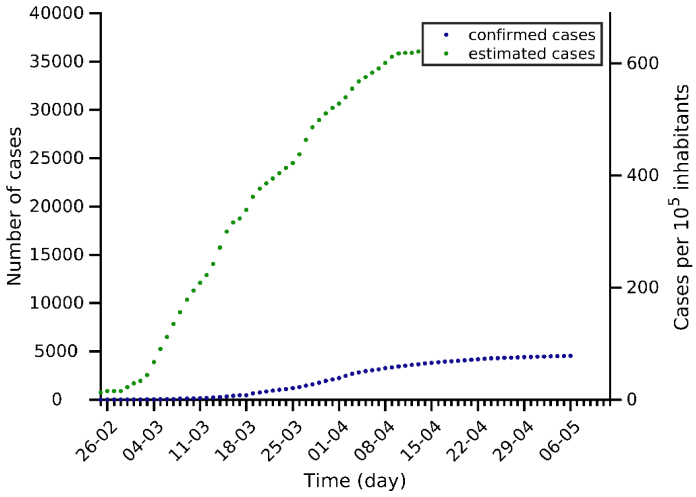


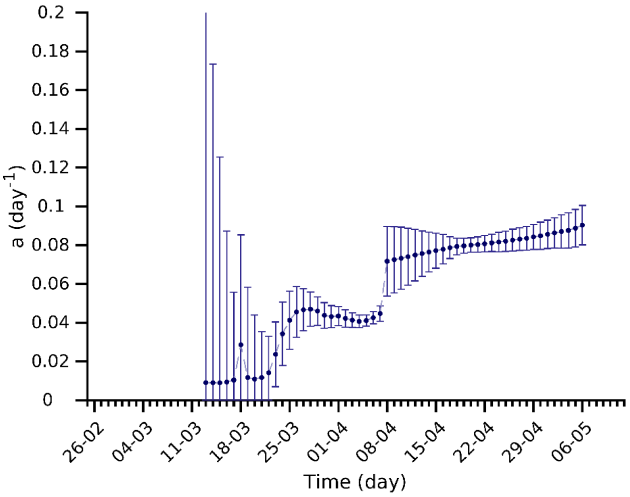


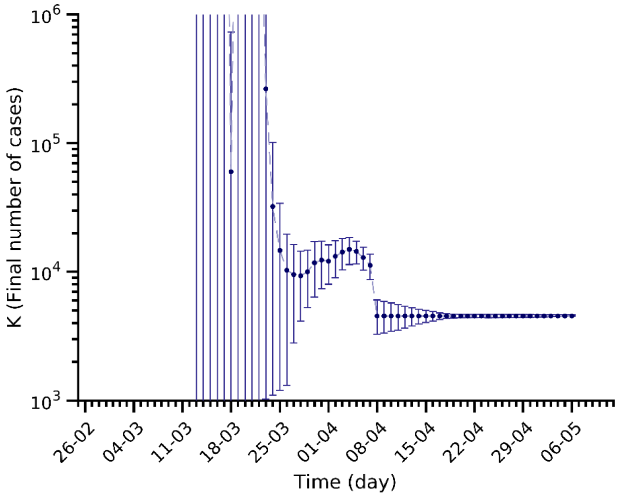


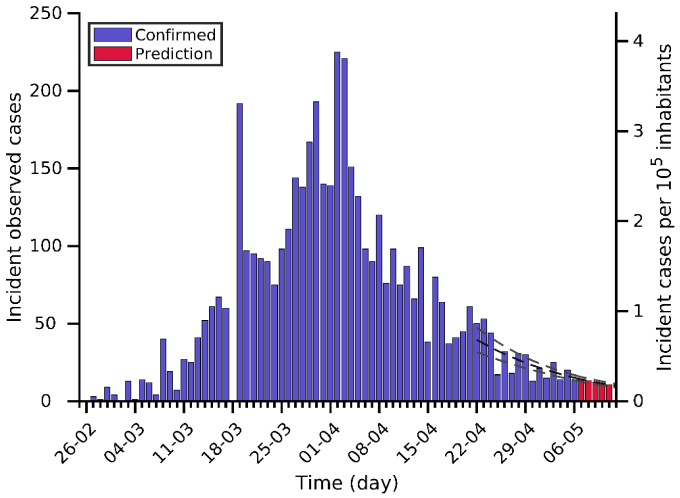
Campania 06-05-2020. Population: 5.8M. Current cumulated incidence: 78/10^5

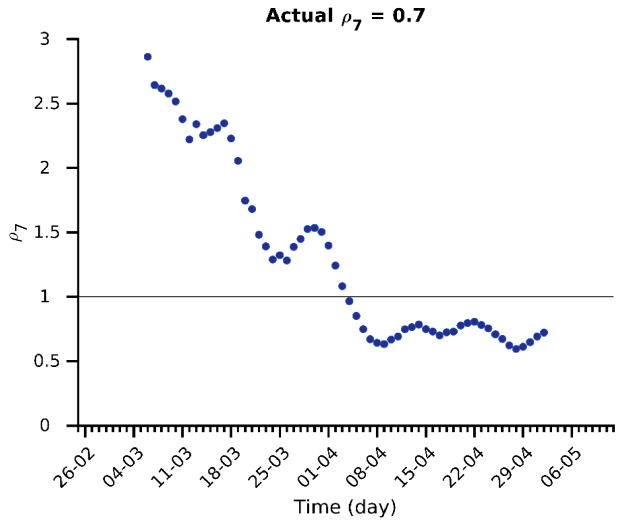


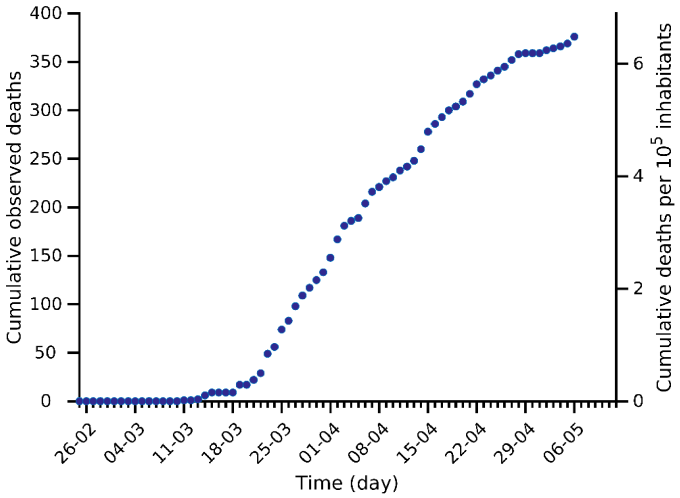


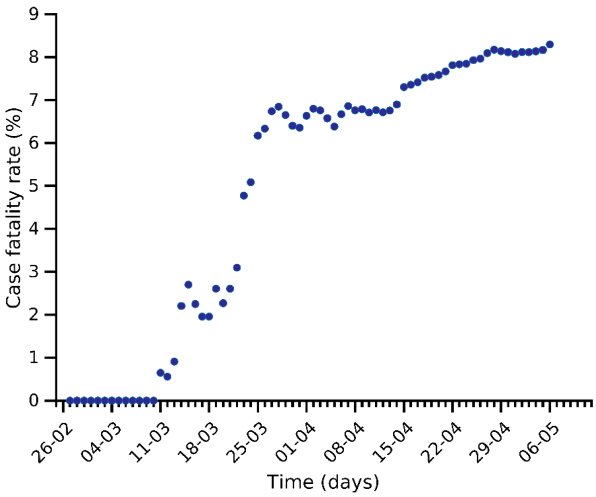




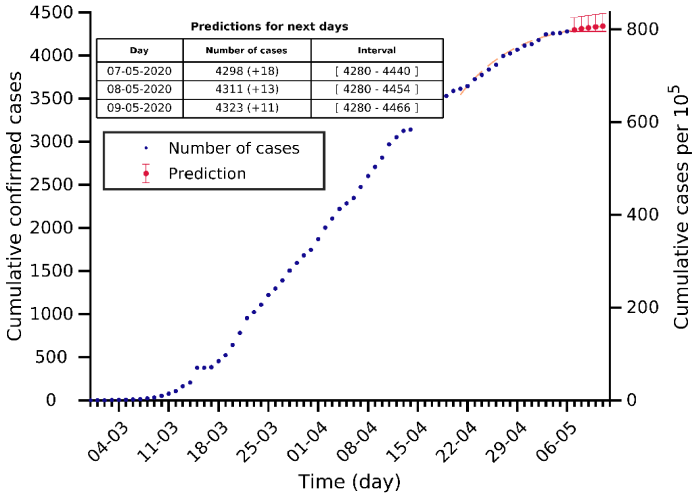


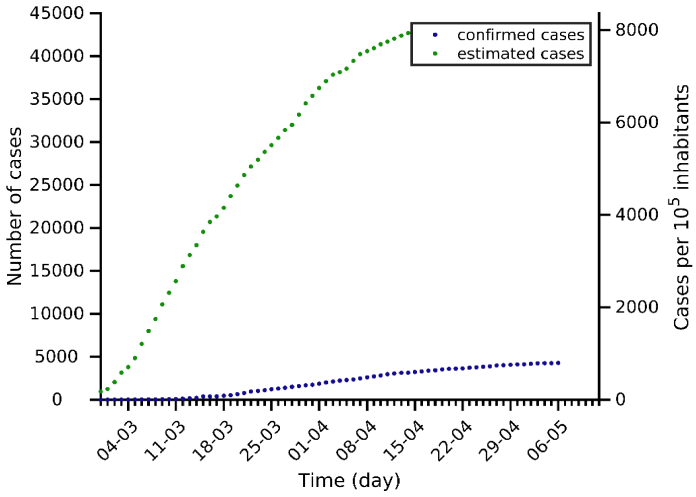


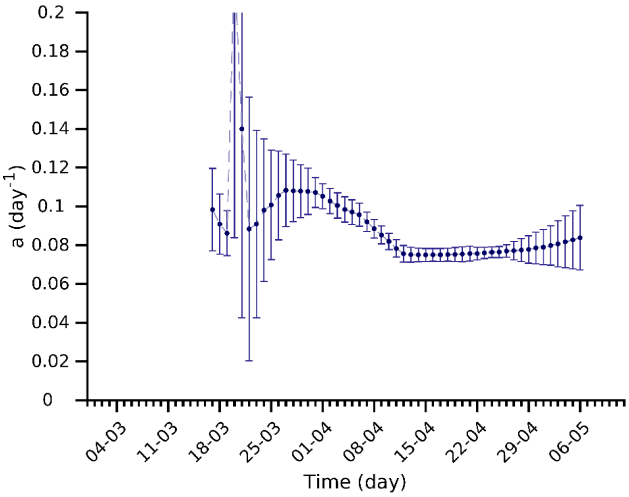


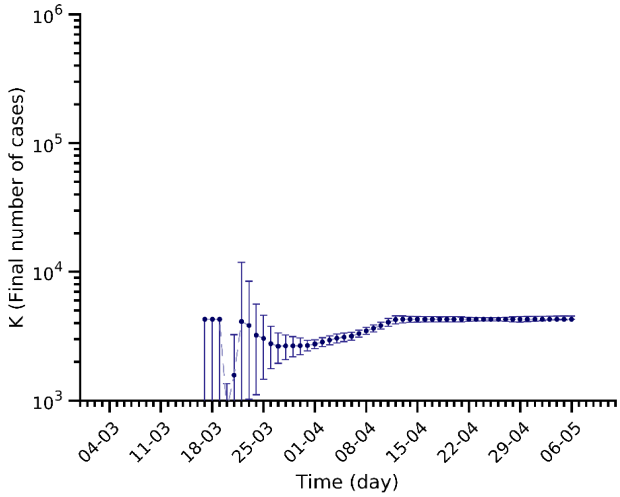


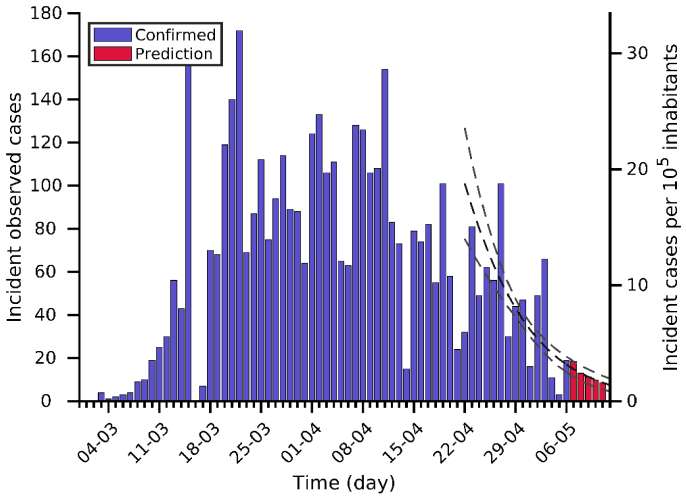
Trento 06-05-2020. Population: 0.5M. Current cumulated incidence: 796/10^5

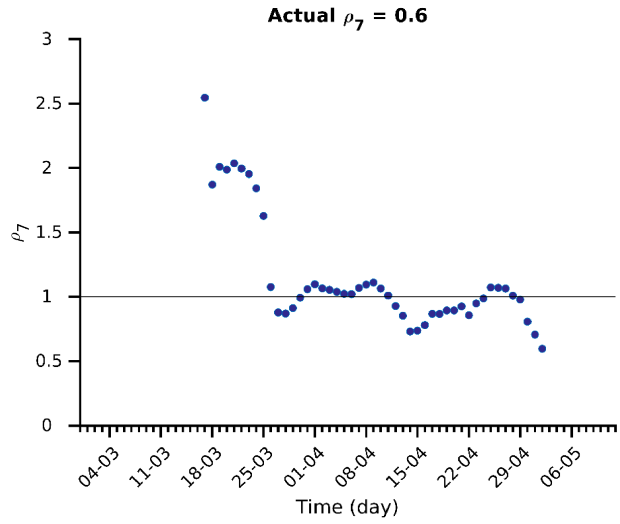


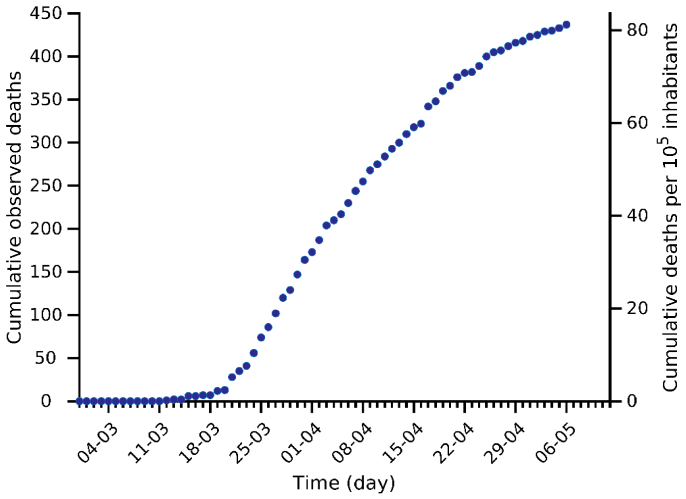


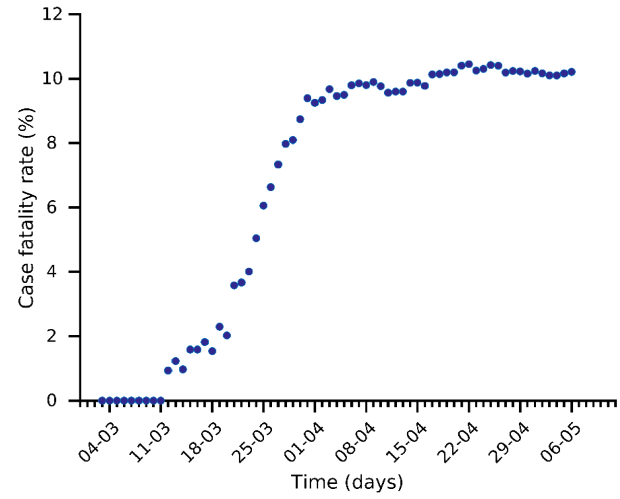




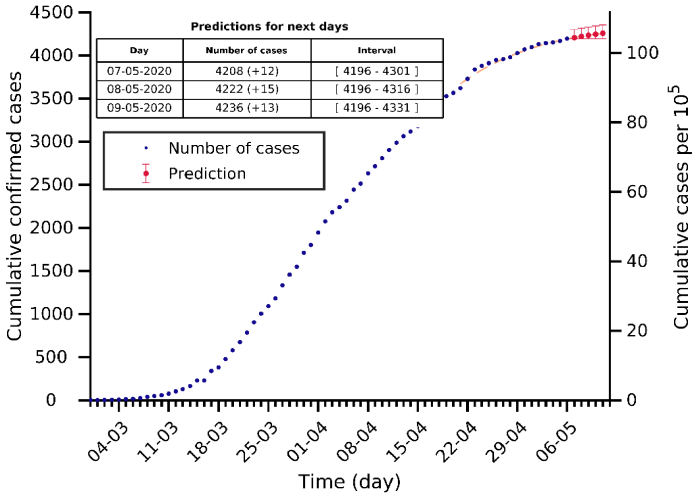


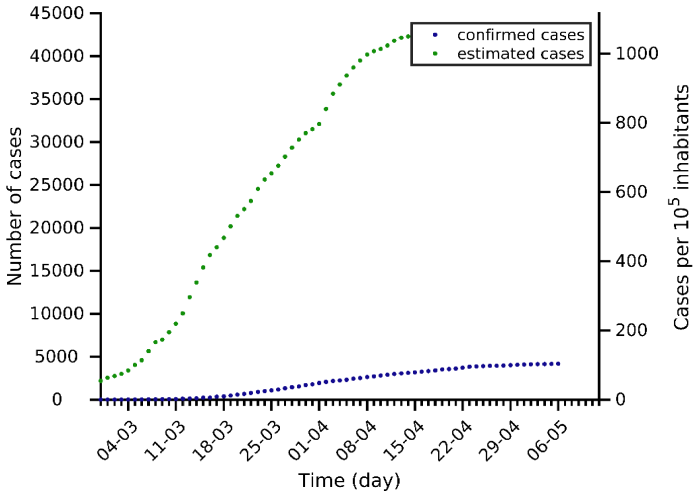


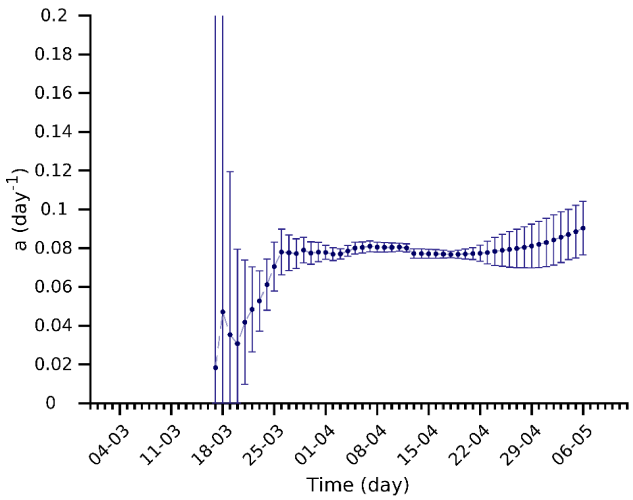


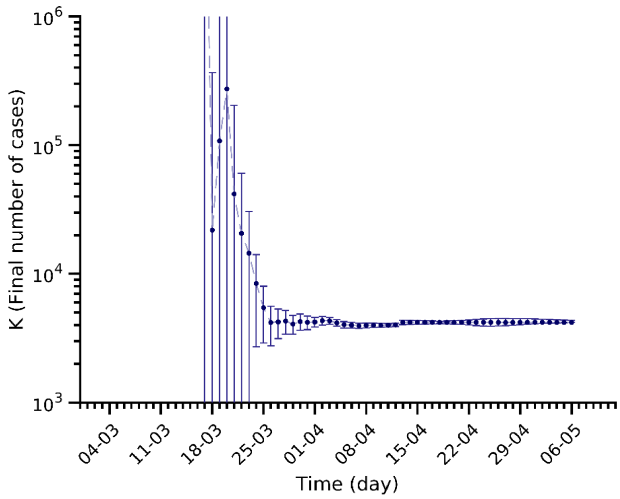


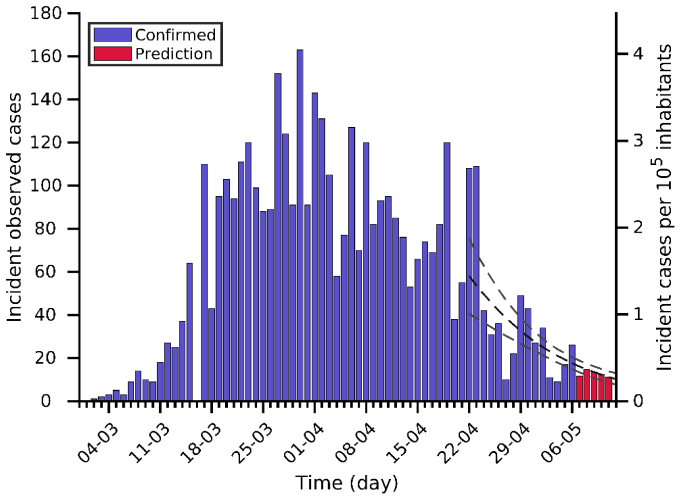
Puglia 06-05-2020. Population: 4.0M. Current cumulated incidence: 104/10^5

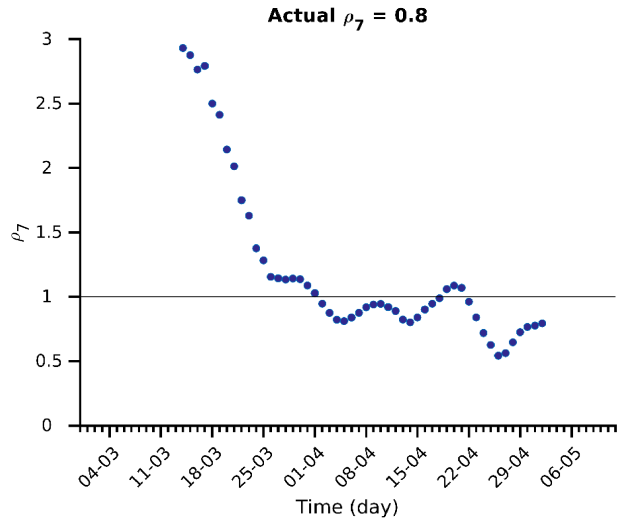


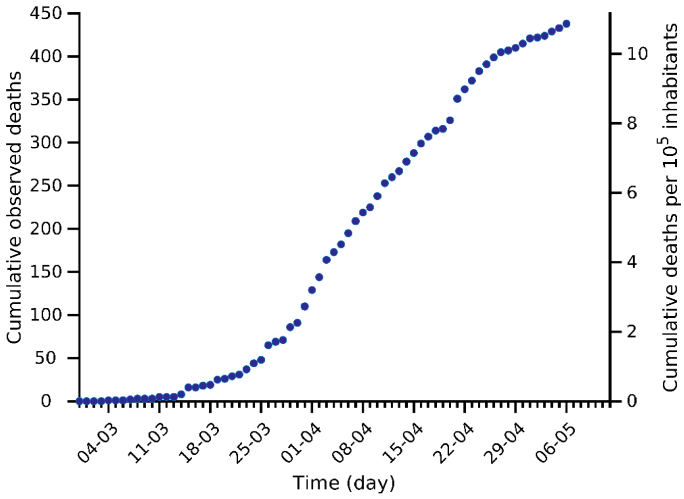


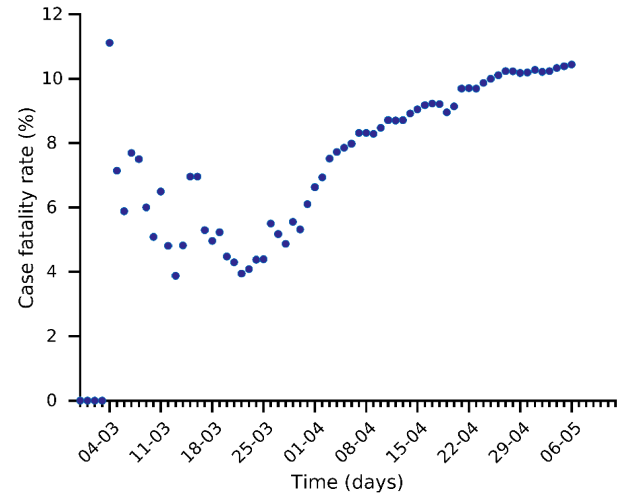




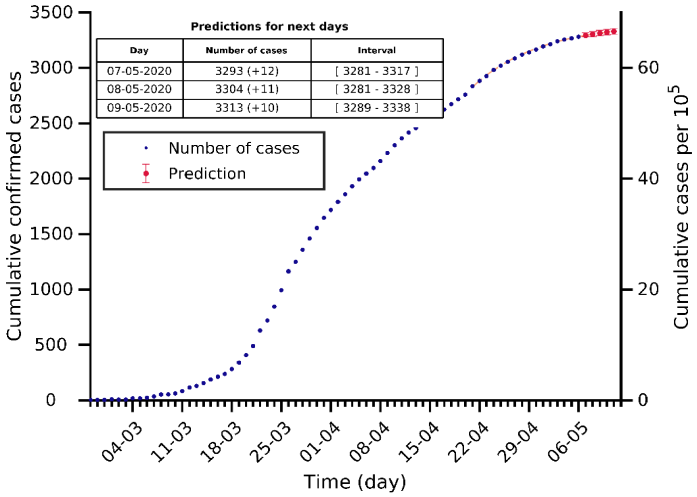


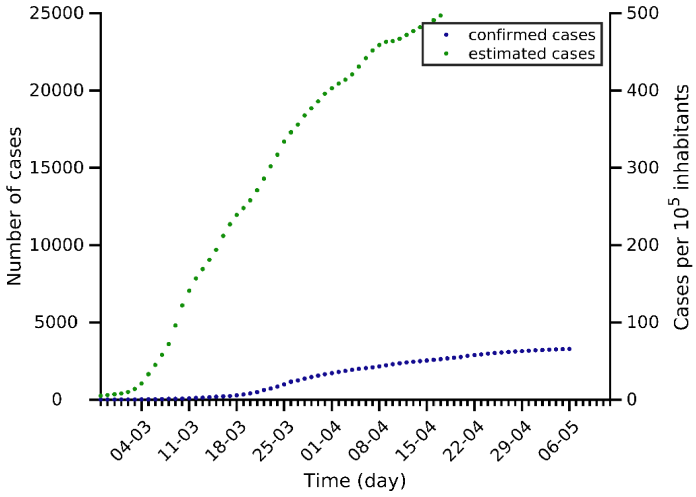


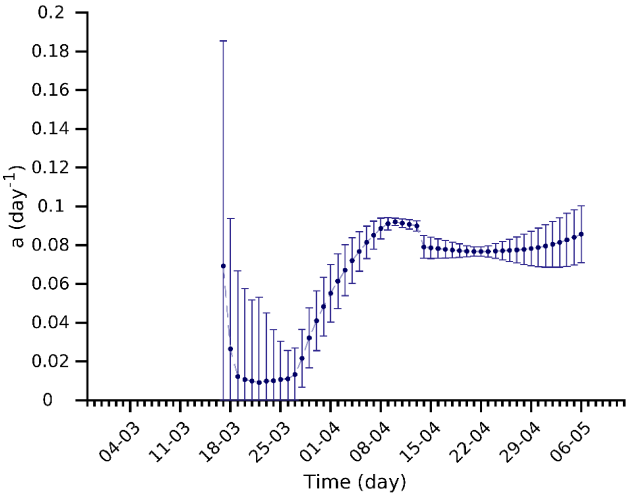


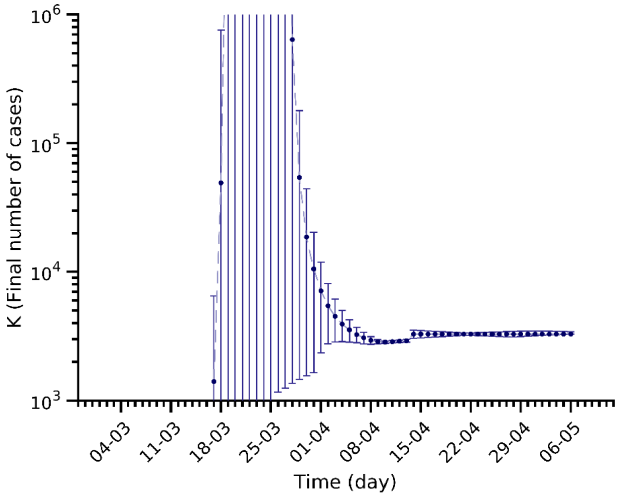


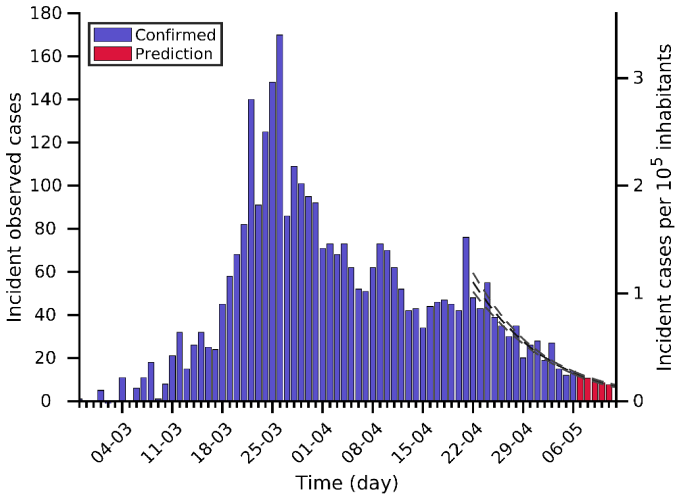
Sicilia 06-05-2020. Population: 5.0M. Current cumulated incidence: $66/10^5$

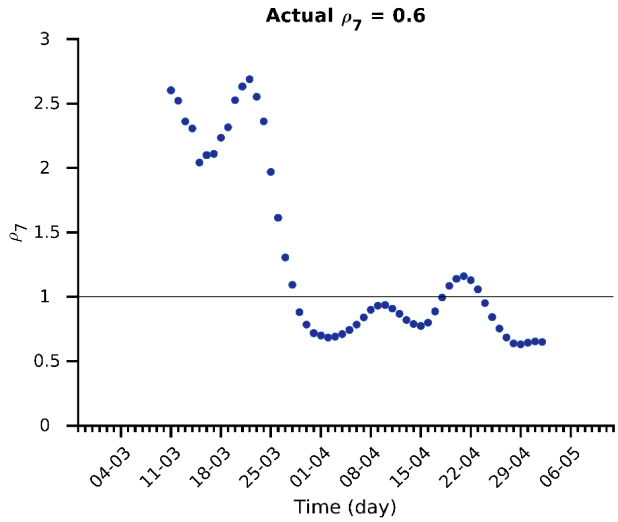


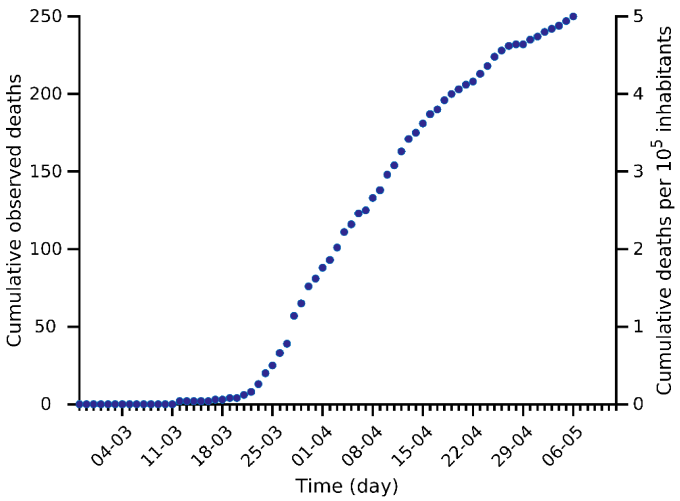


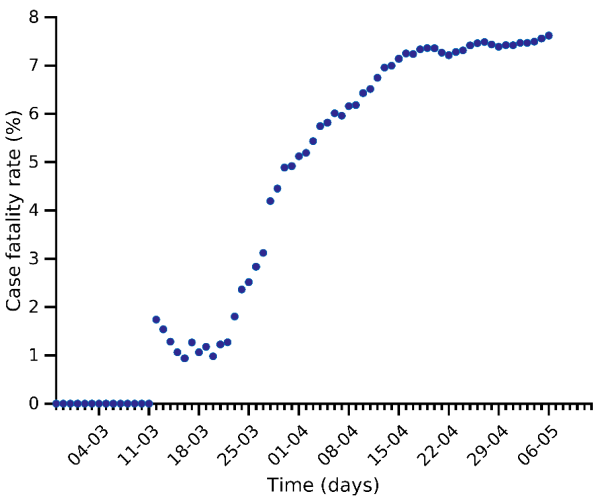




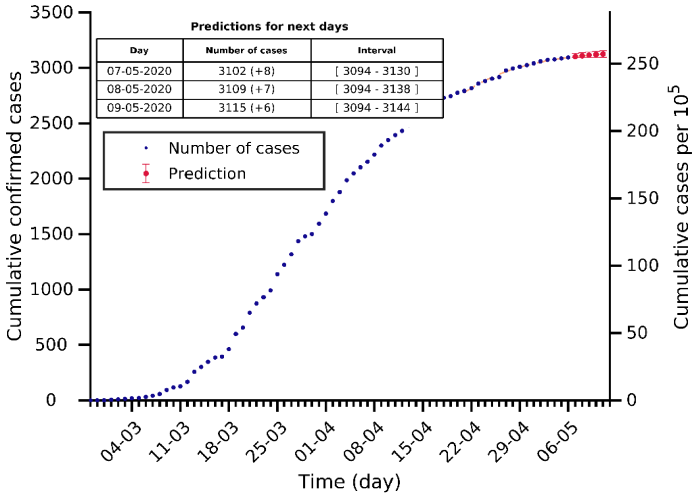


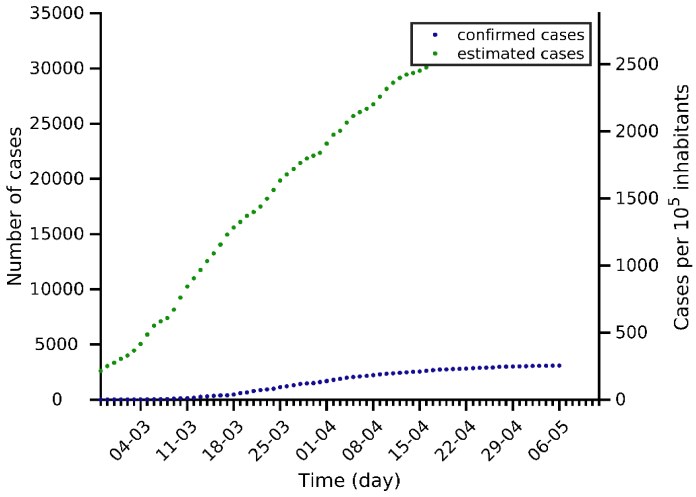


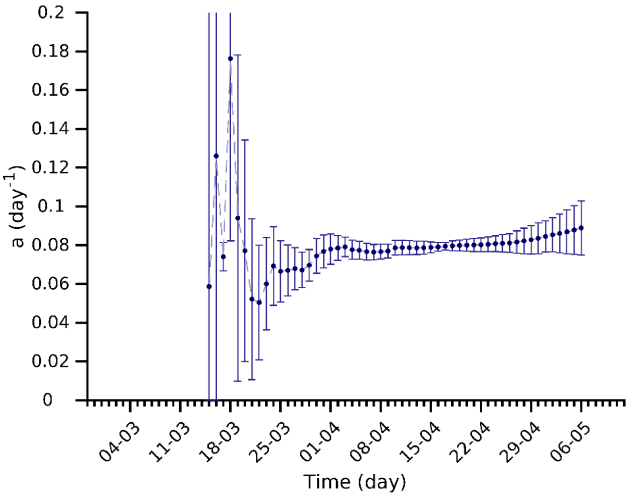


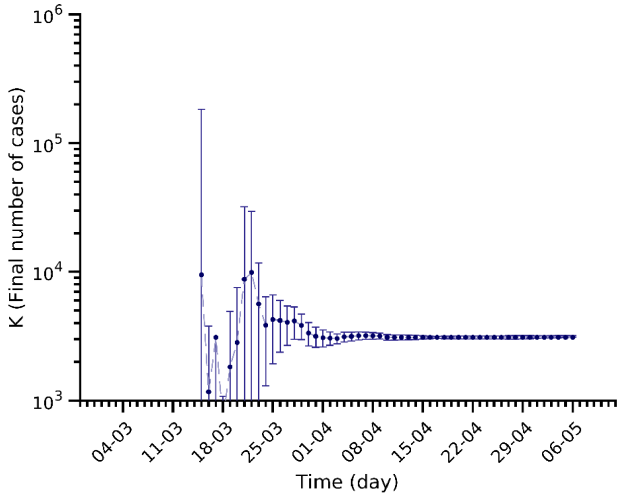


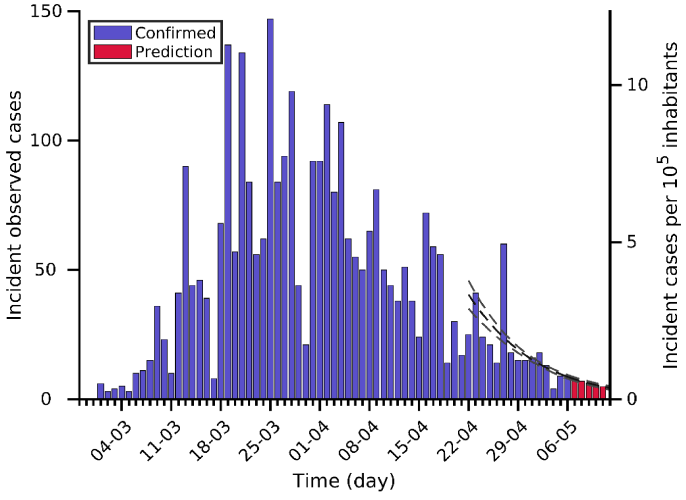
Friuli Venezia Giulia 06-05-2020. Population: 1.2M. Current cumulated incidence: 2

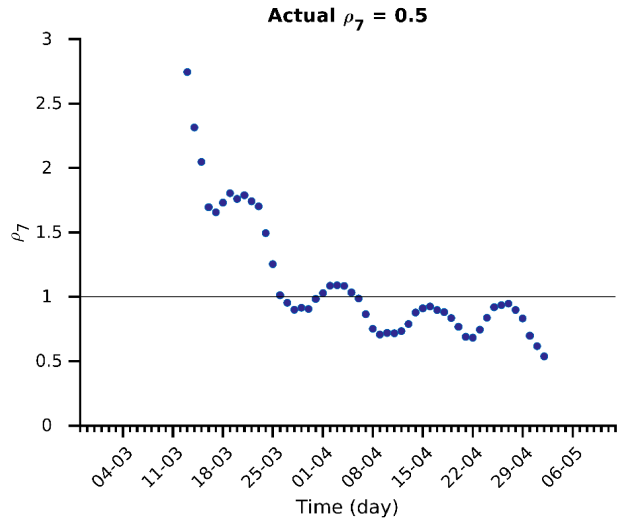


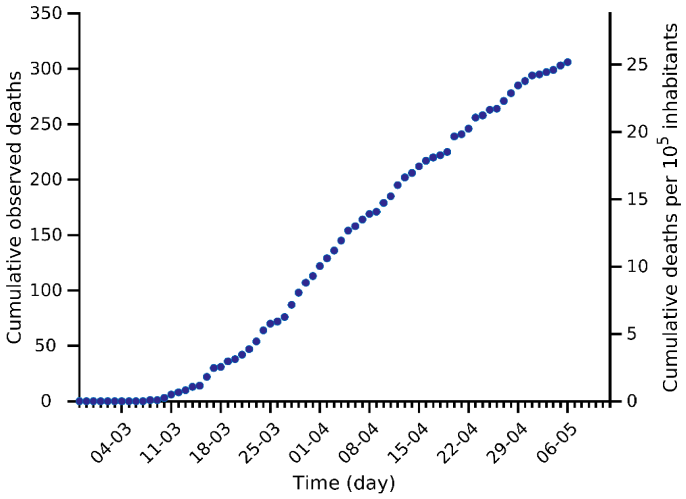


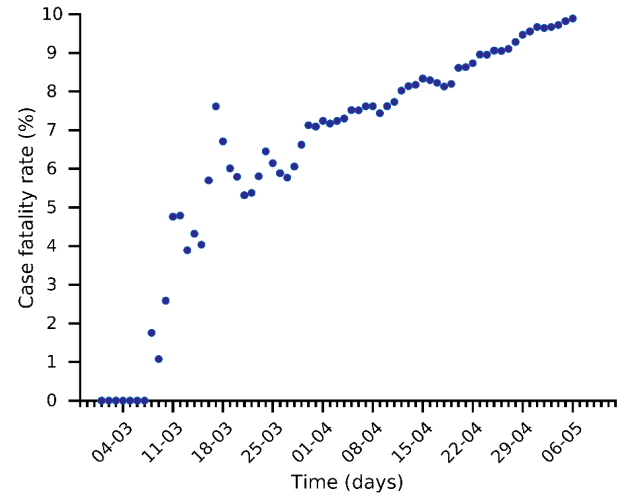




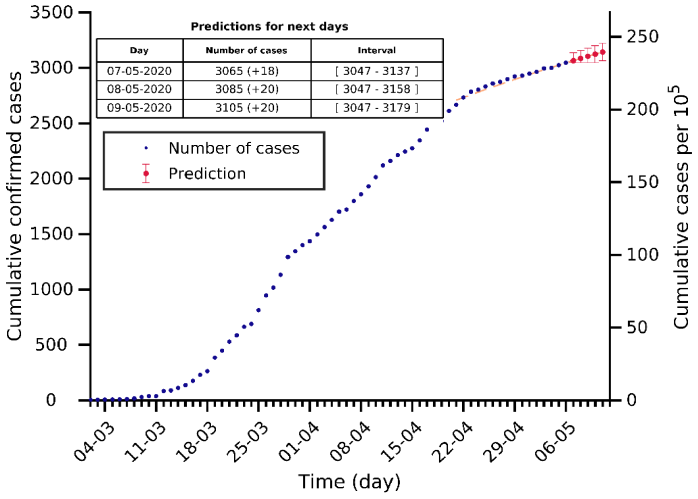


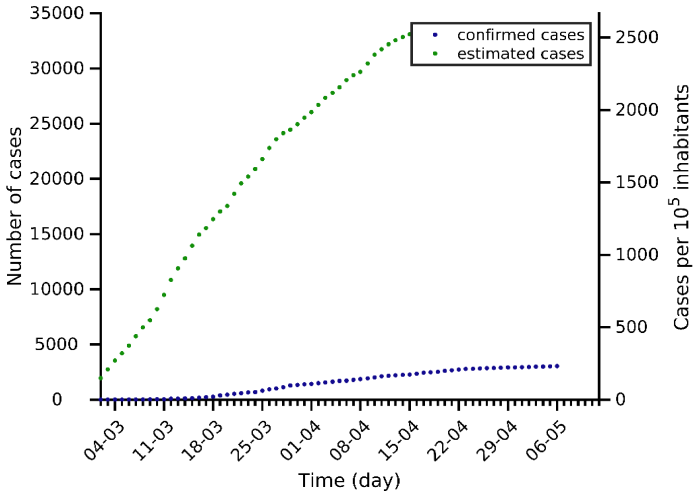


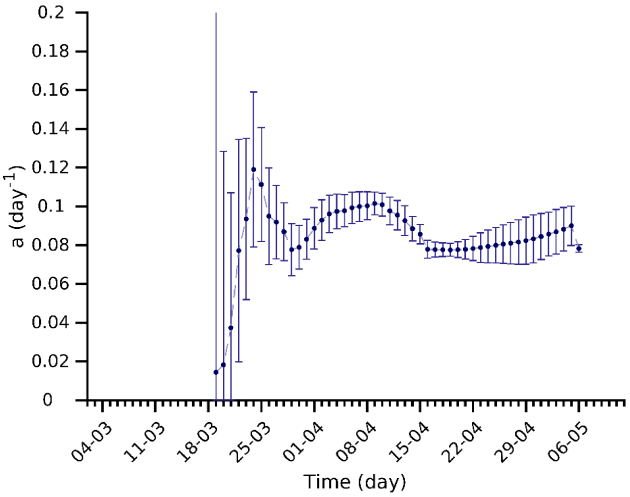


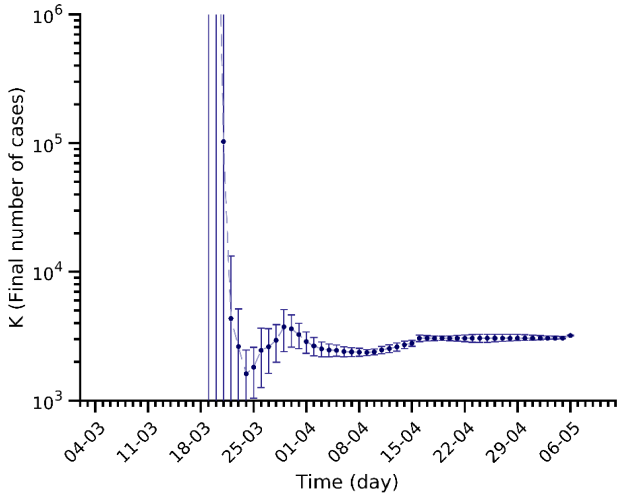


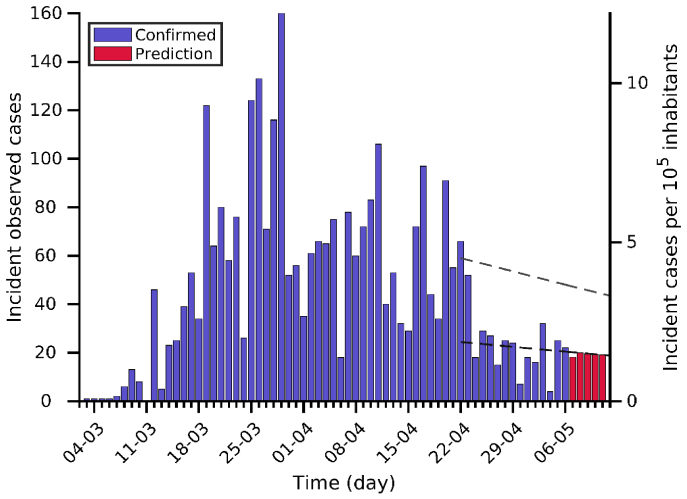
Abruzzo 06-05-2020. Population: 1.3M. Current cumulated incidence: 232/10^5

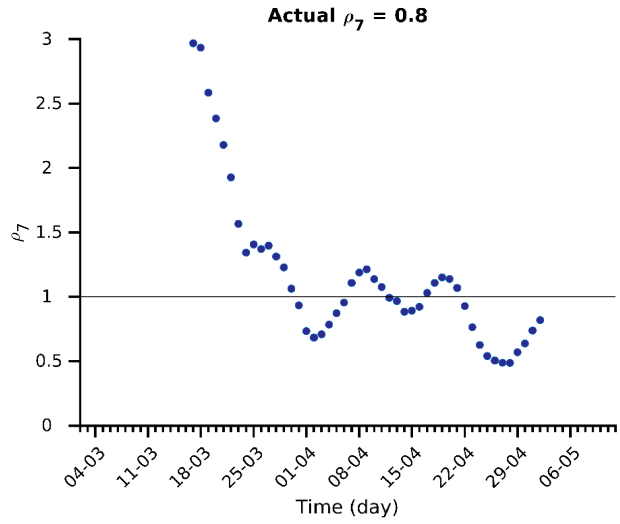


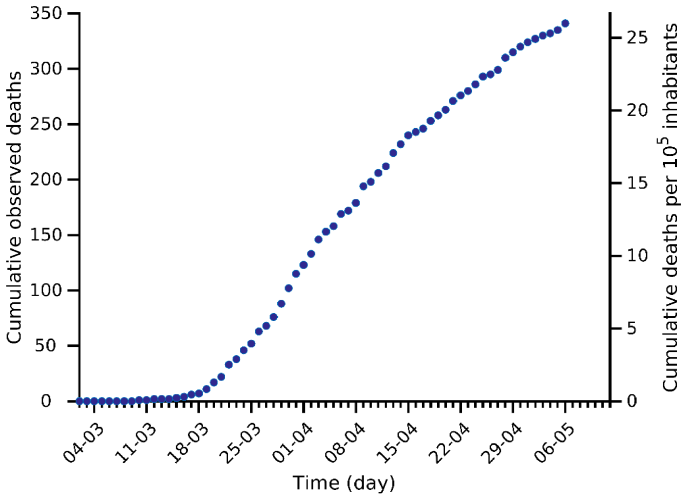


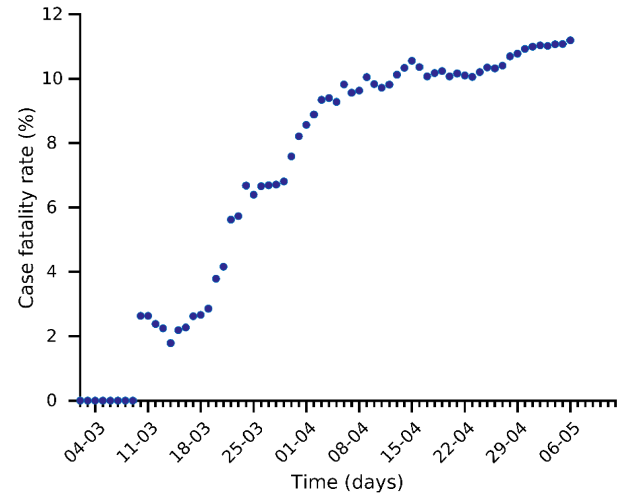




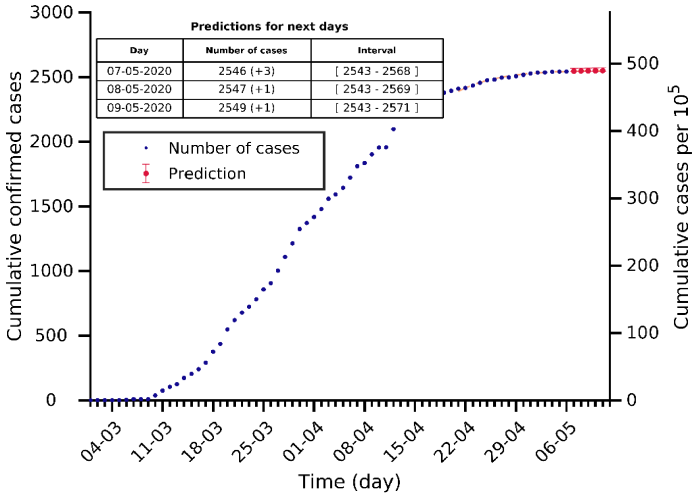


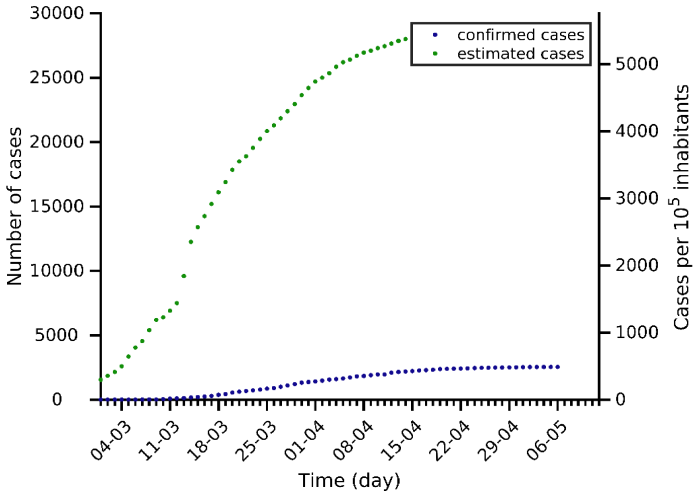


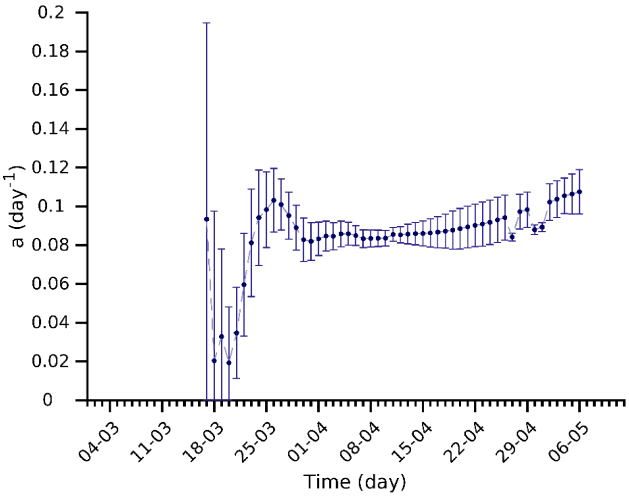


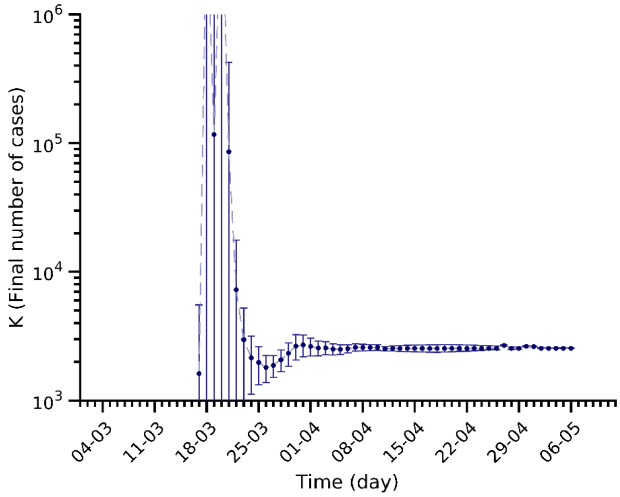


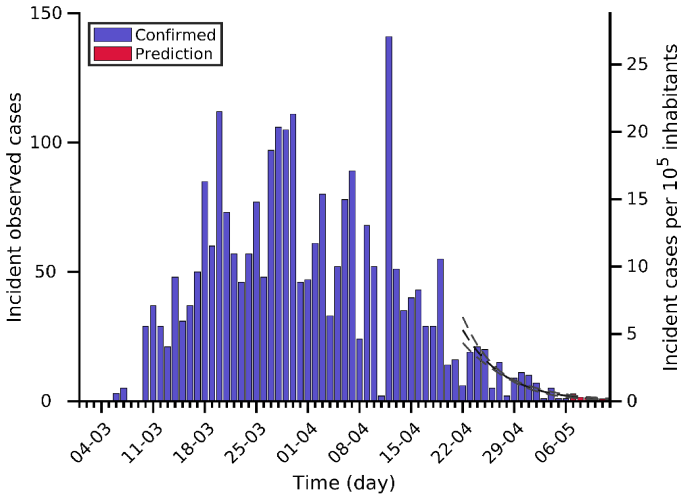
Bolzano 06-05-2020. Population: 0.5M. Current cumulated incidence: $488/10^5$

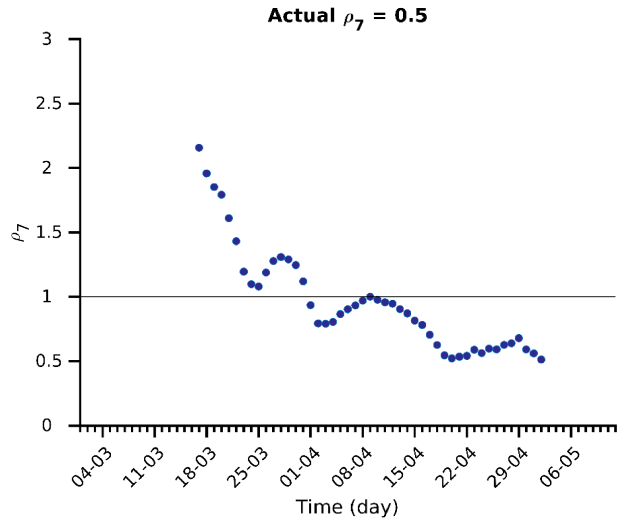


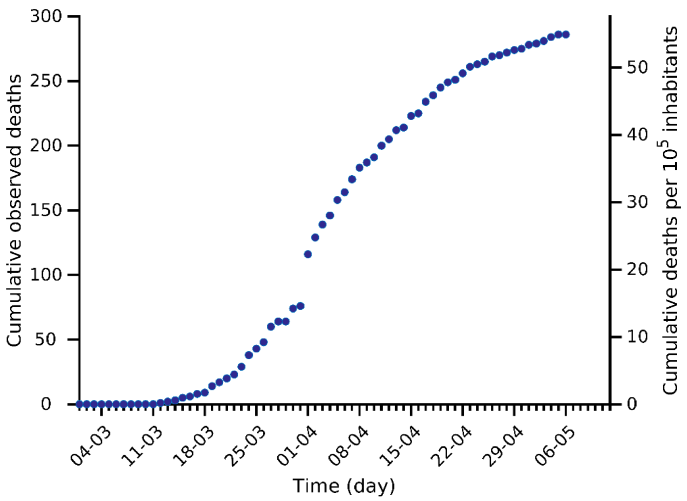


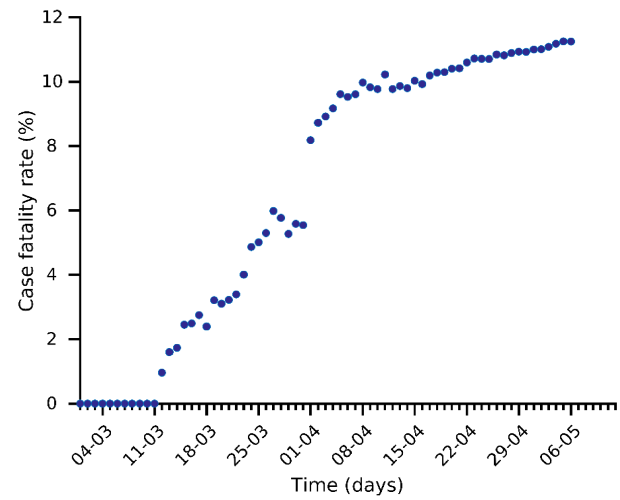




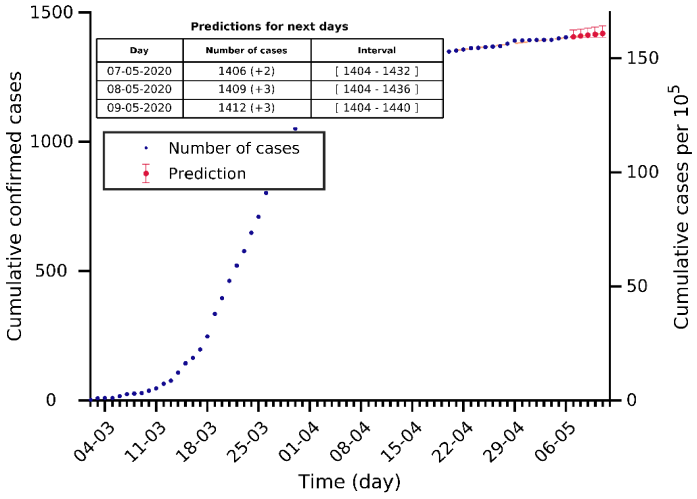


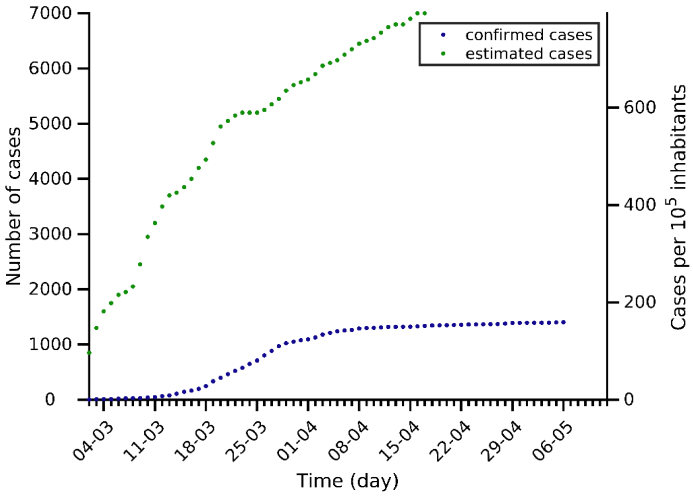


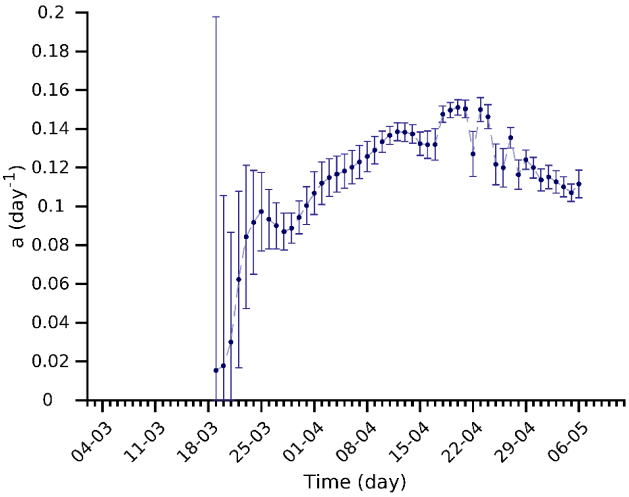


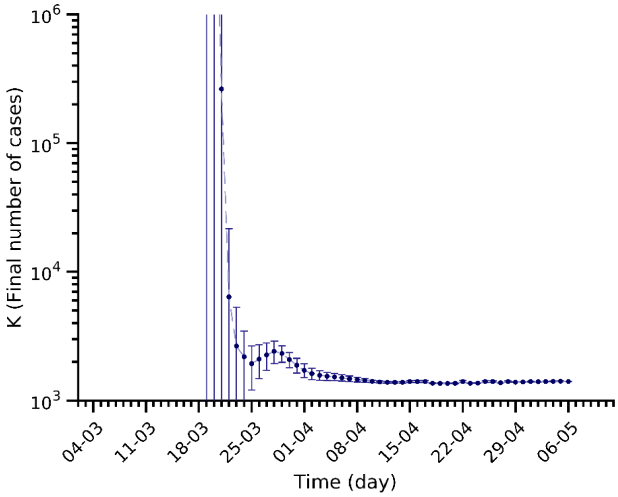


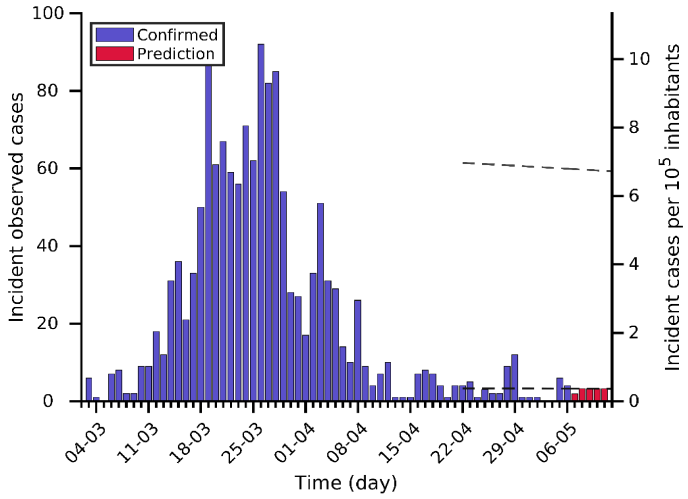
Umbria 06-05-2020. Population: 0.9M. Current cumulated incidence: 159/10^5

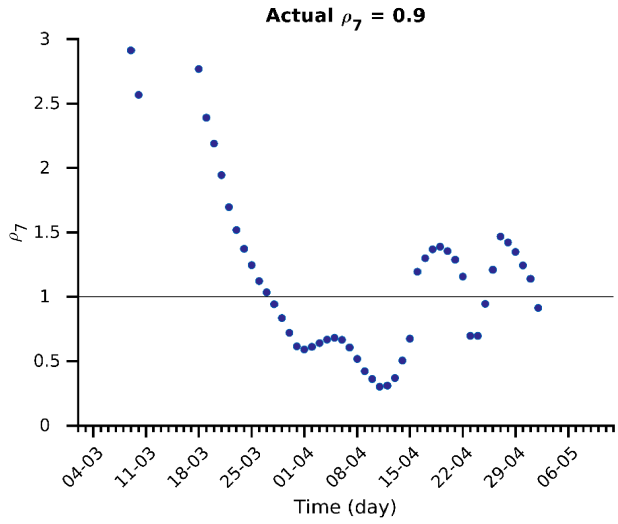


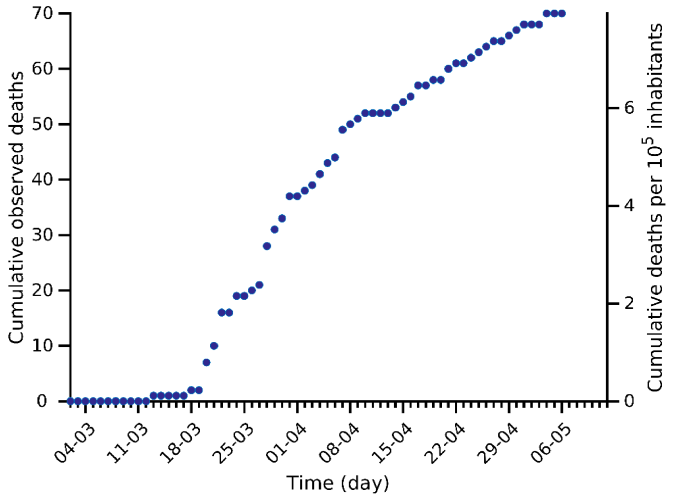


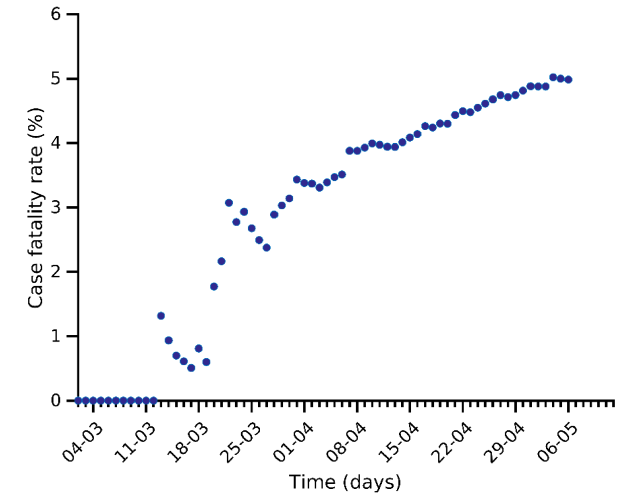




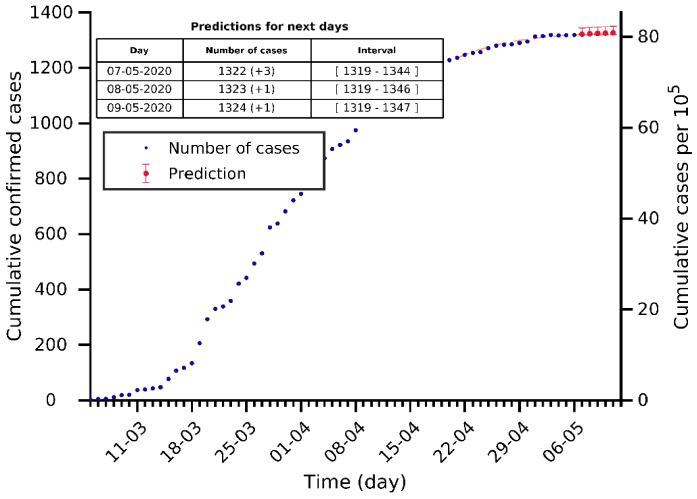


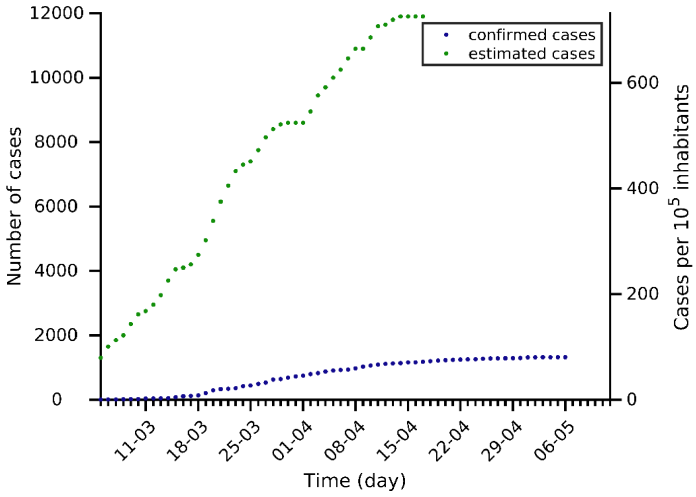


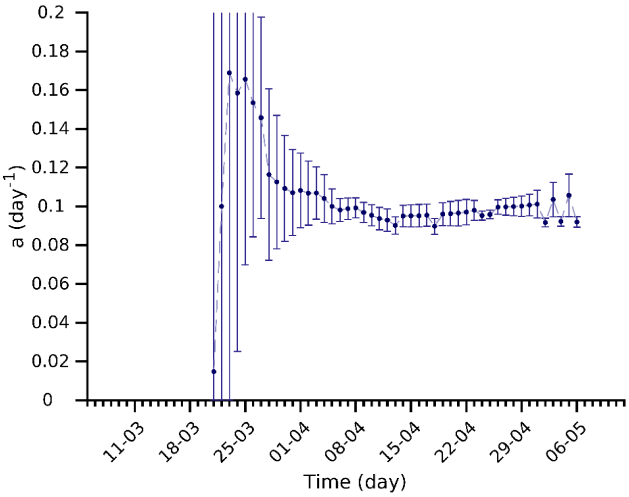


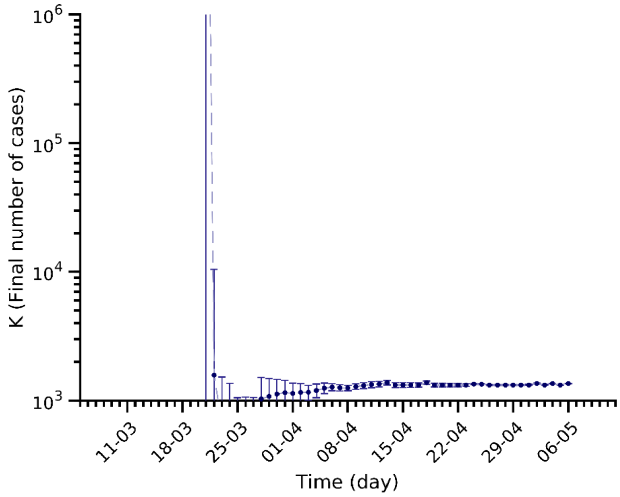


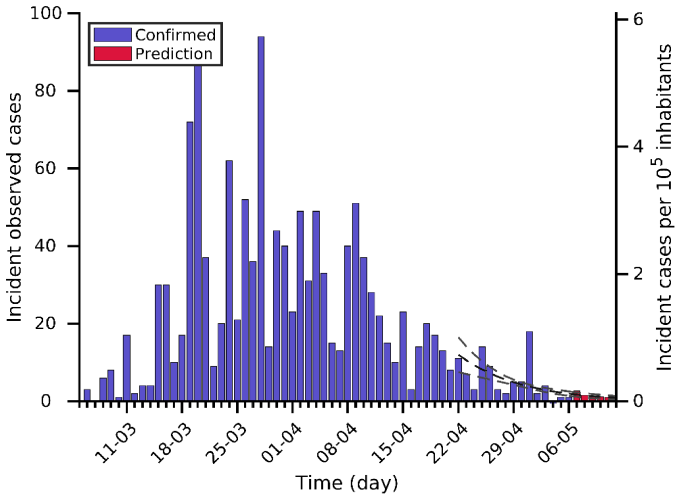
Sardegna 06-05-2020. Population: 1.6M. Current cumulated incidence: 80/10^5

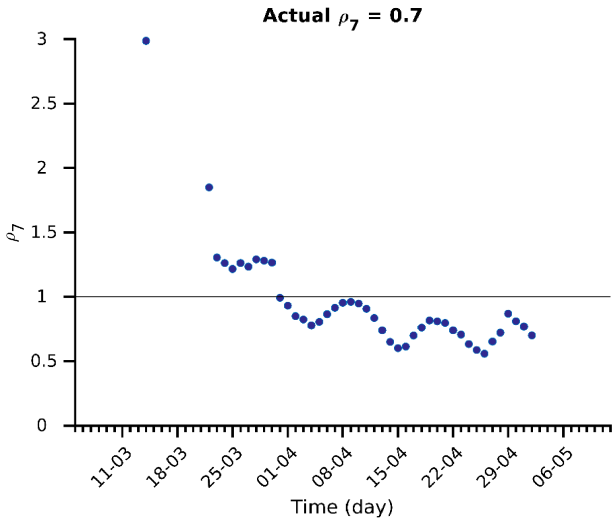


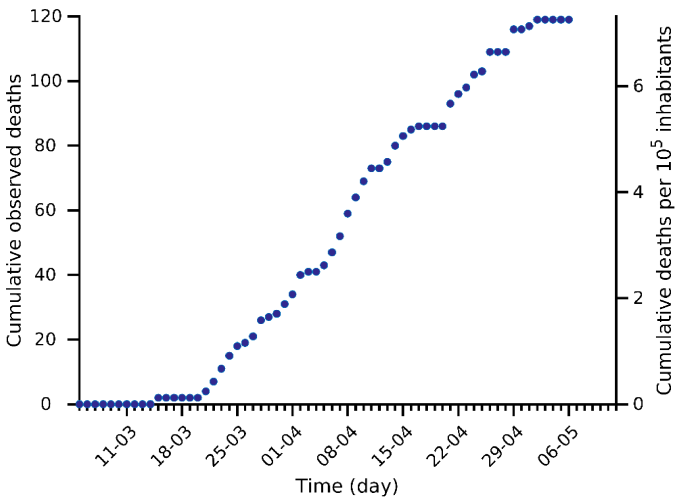


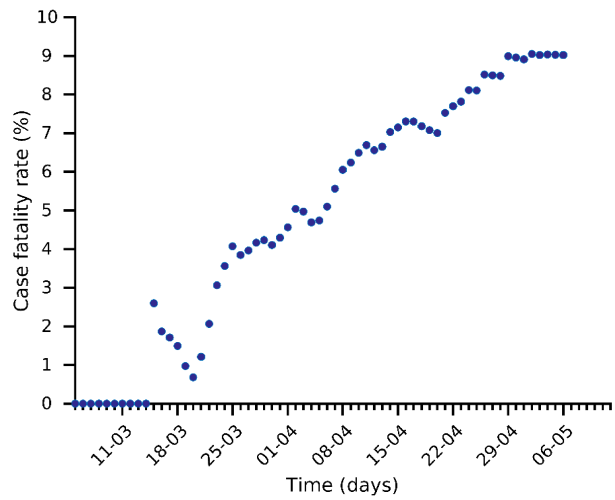




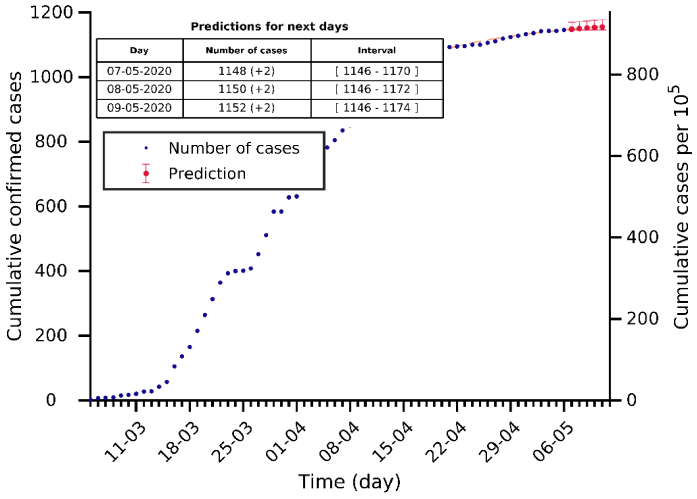


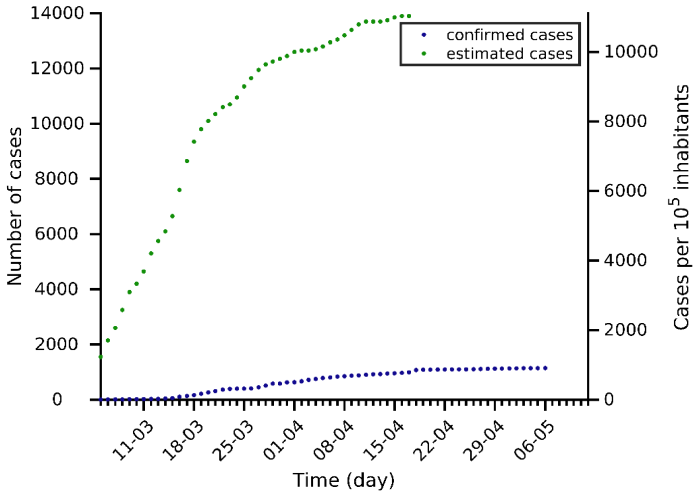


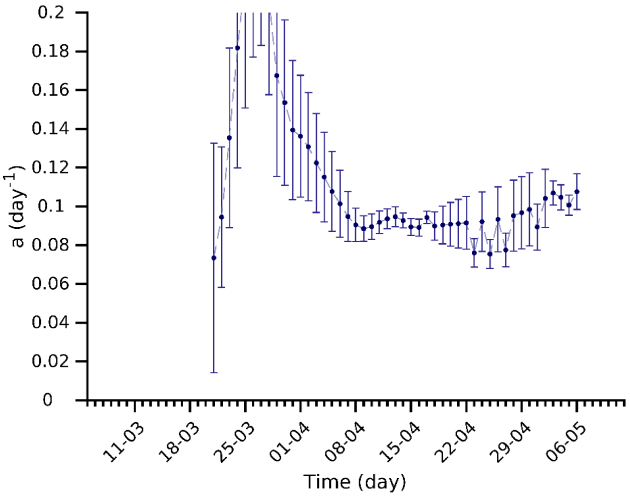


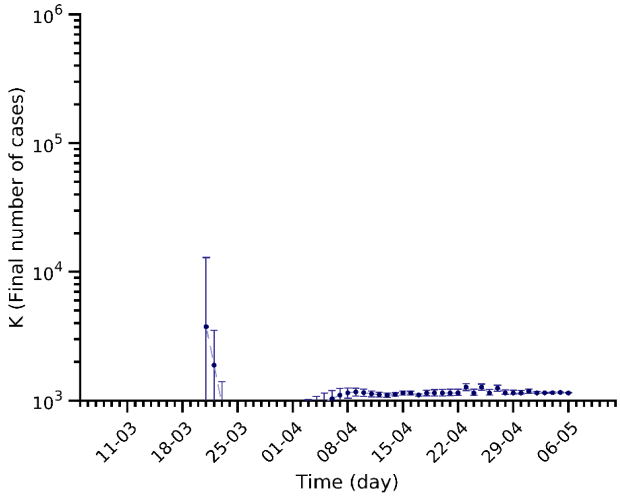


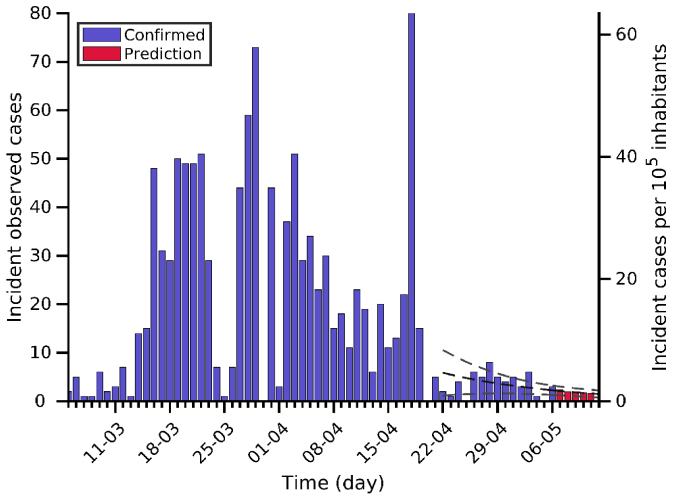
Valle dAosta 06-05-2020. Population: 0.1M. Current cumulated incidence: 910/10^5

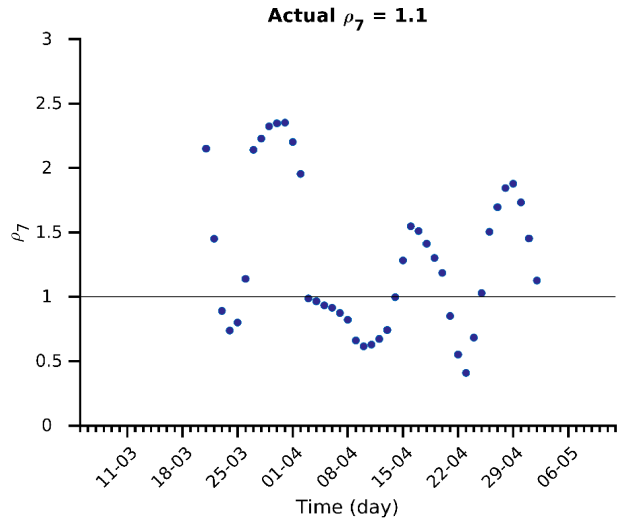


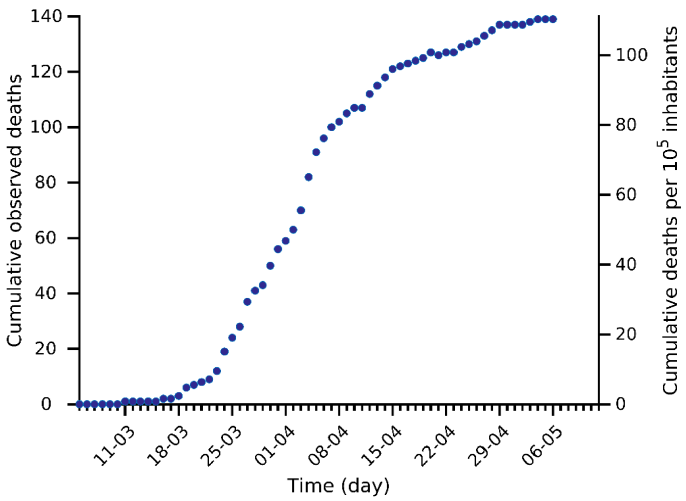


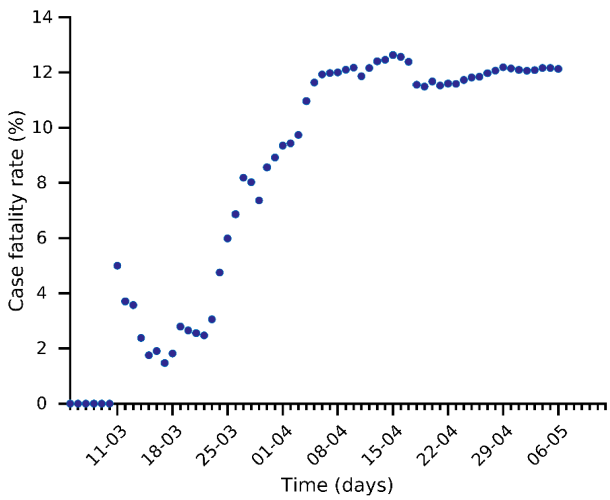




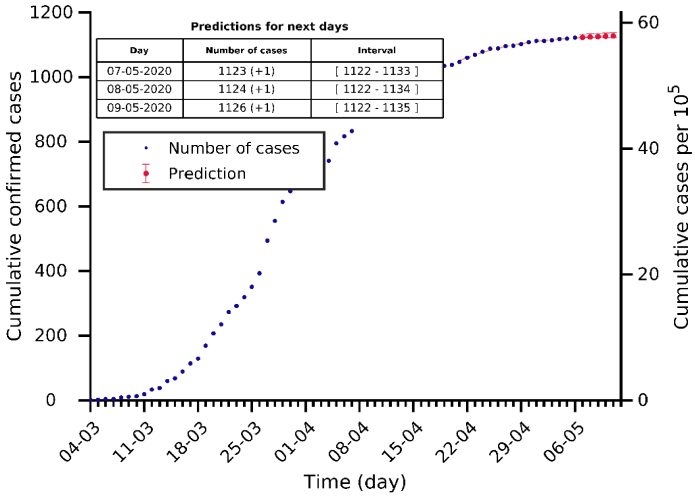


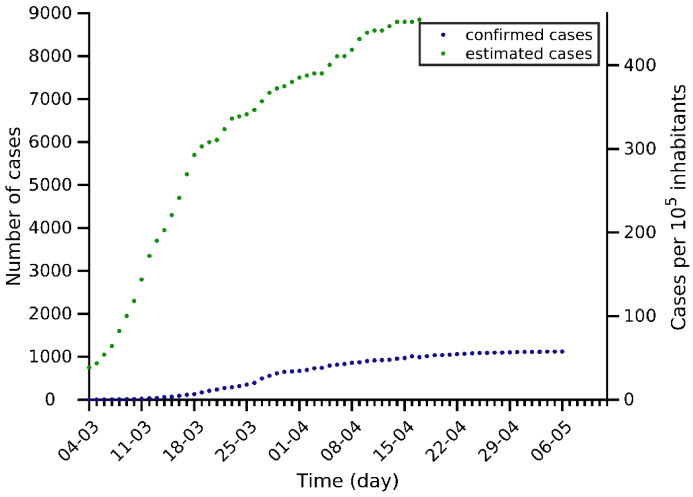


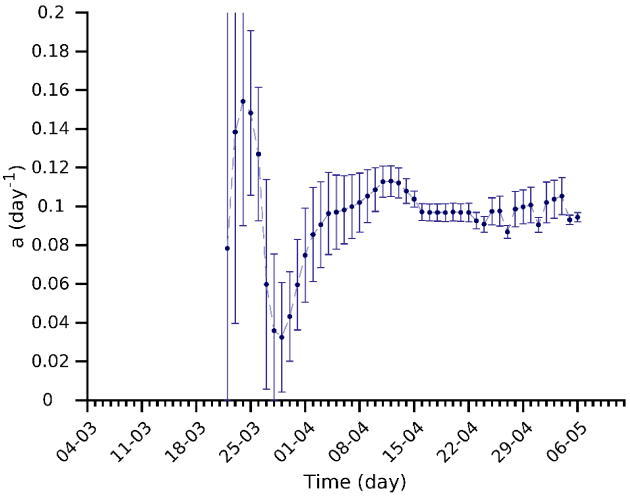


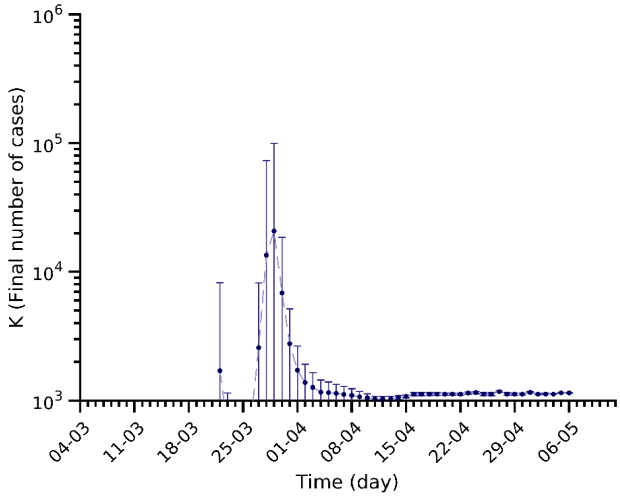


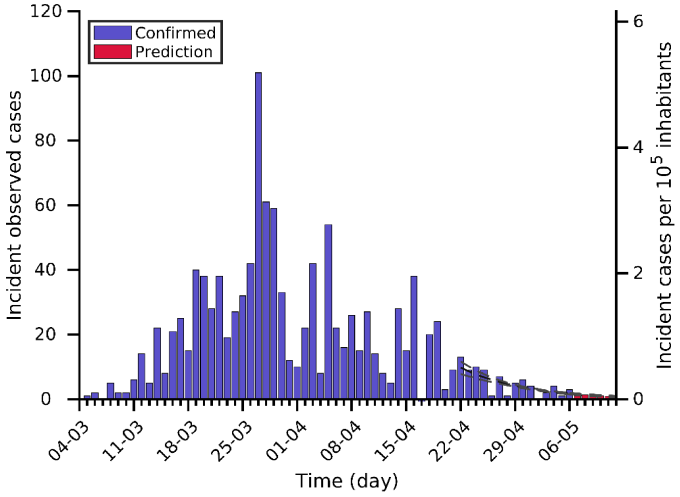
Calabria 06-05-2020. Population: 1.9M. Current cumulated incidence: $58/10^5$

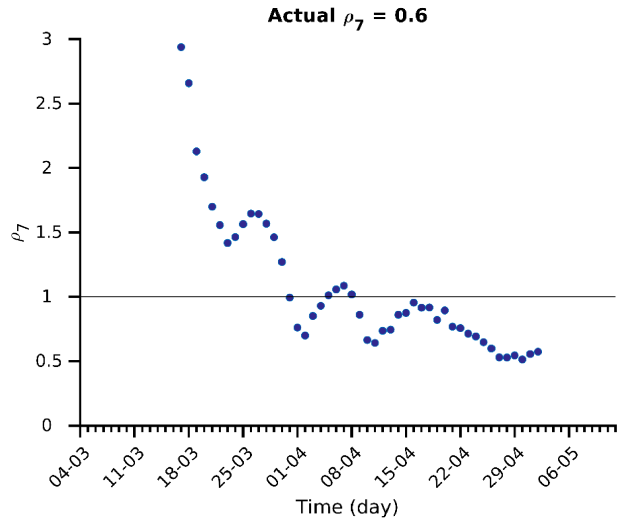


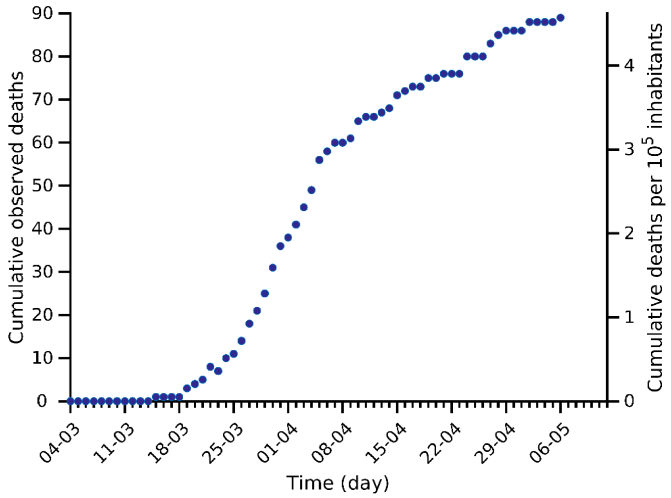


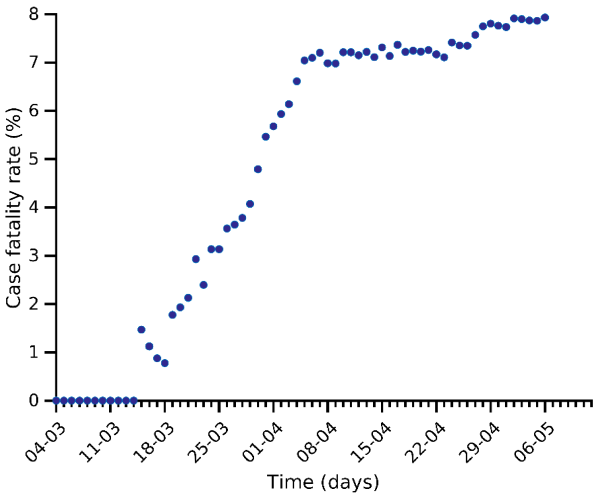




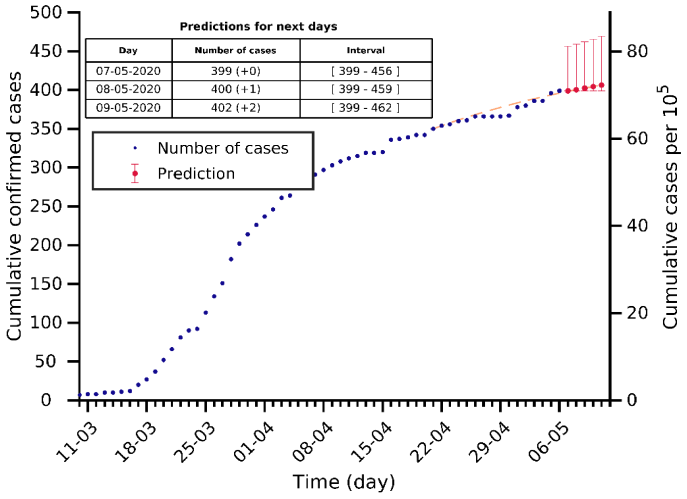


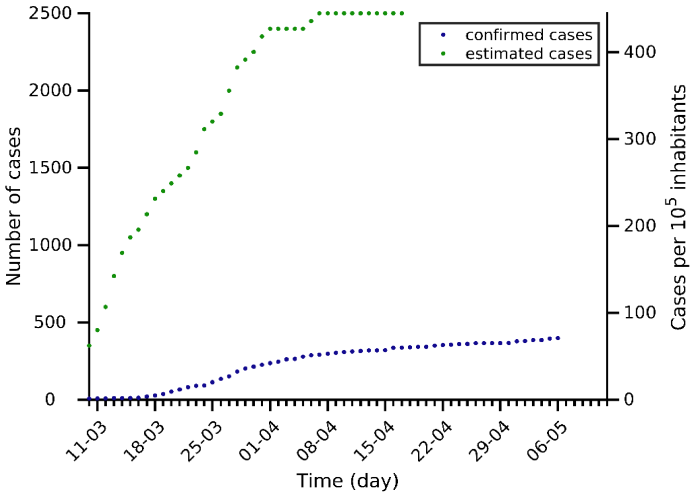


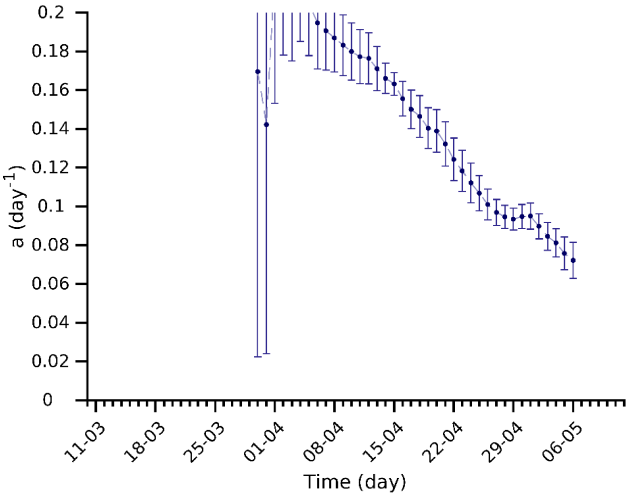


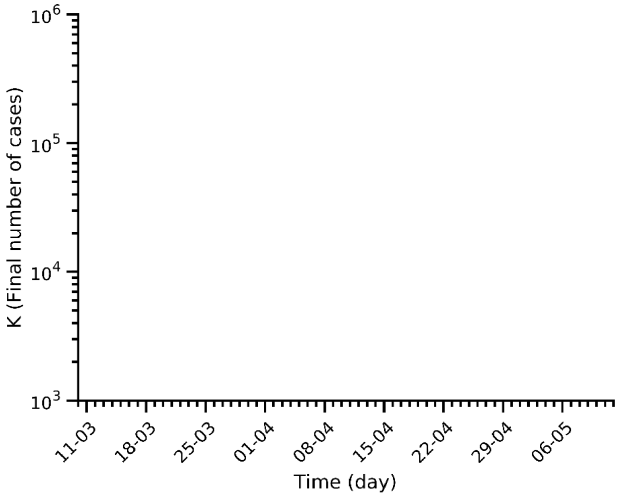


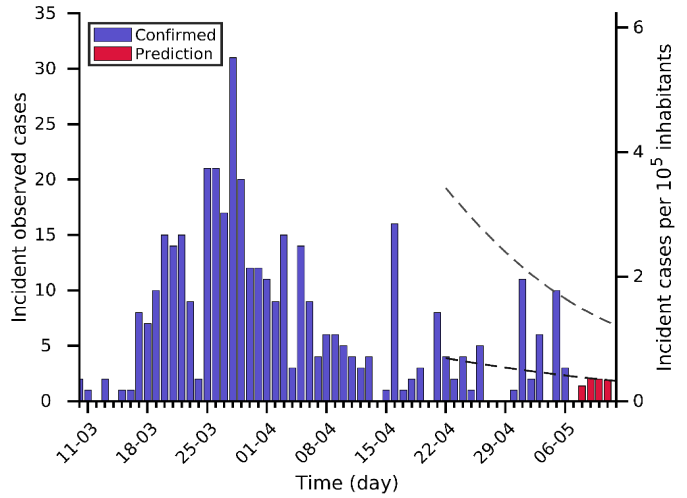
Basilicata 06-05-2020. Population: 0.6M. Current cumulated incidence: 71/10^5

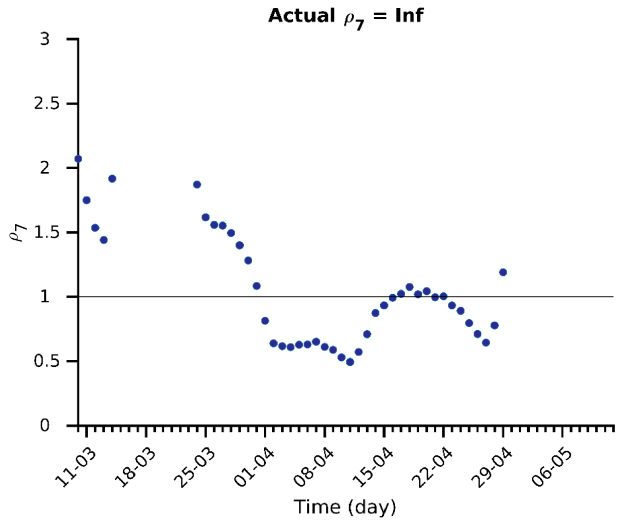


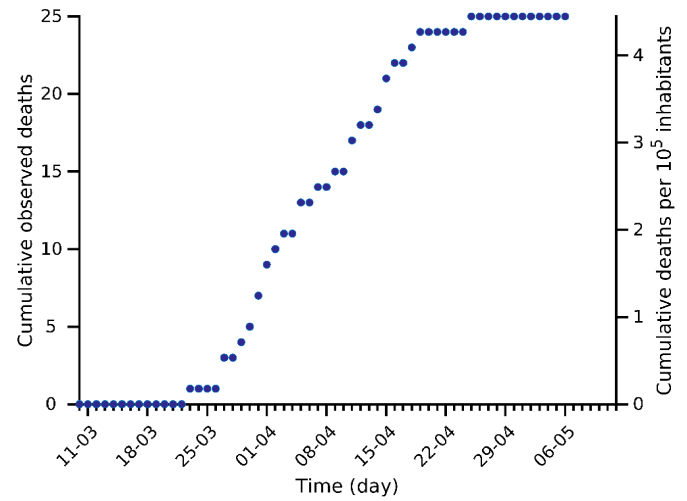


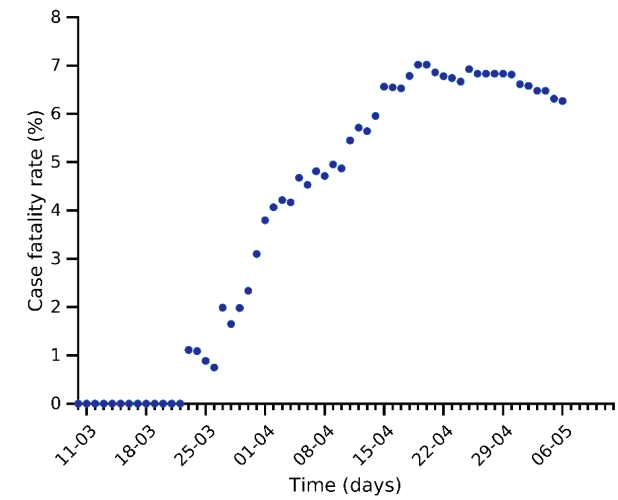




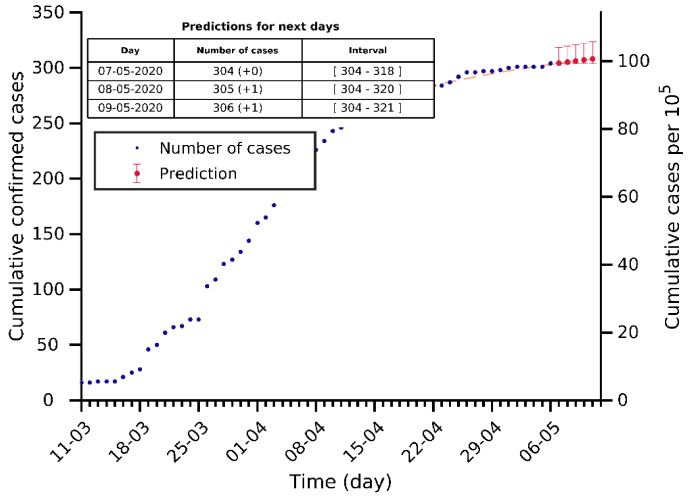


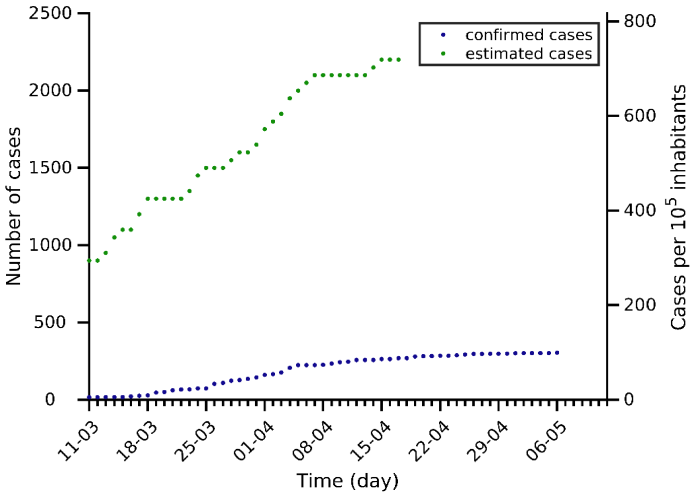


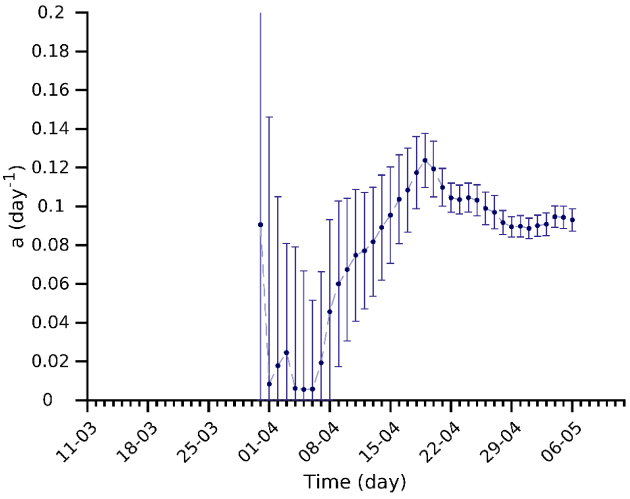


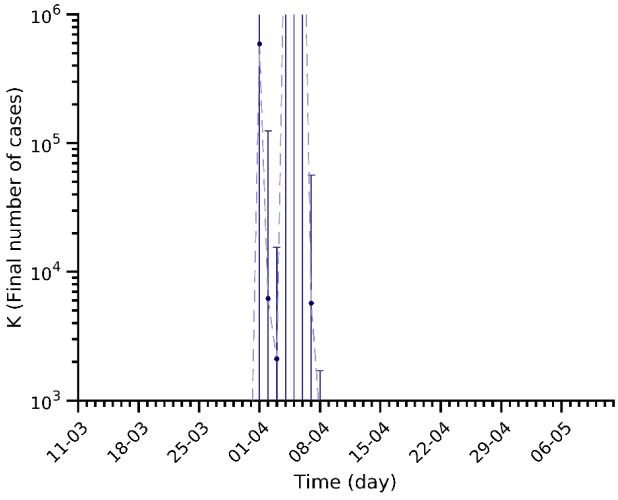


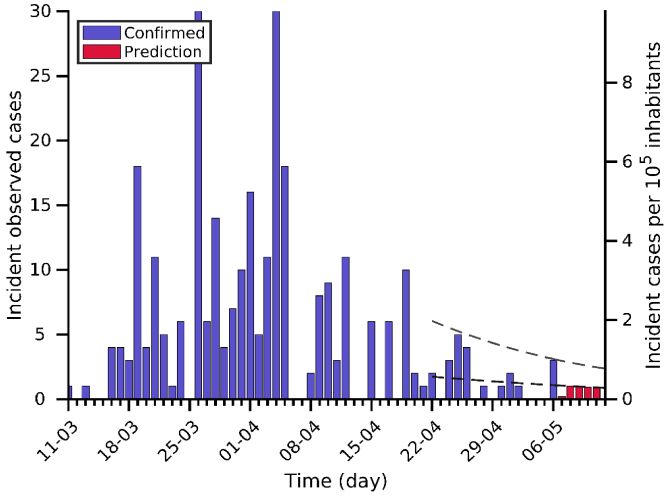
Molise 06-05-2020. Population: 0.3M. Current cumulated incidence: 99/10^5

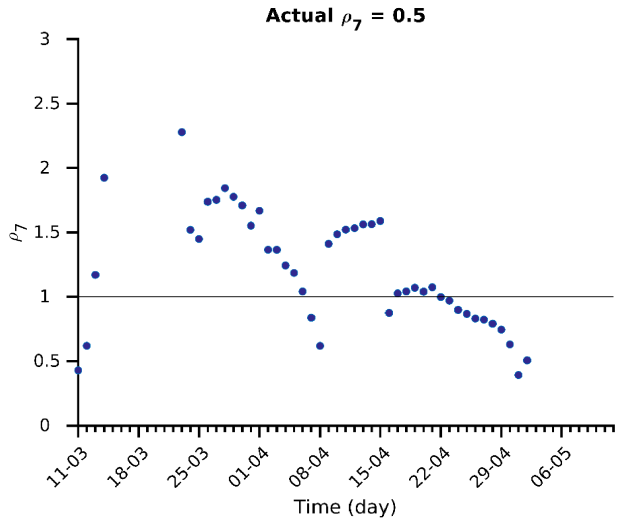


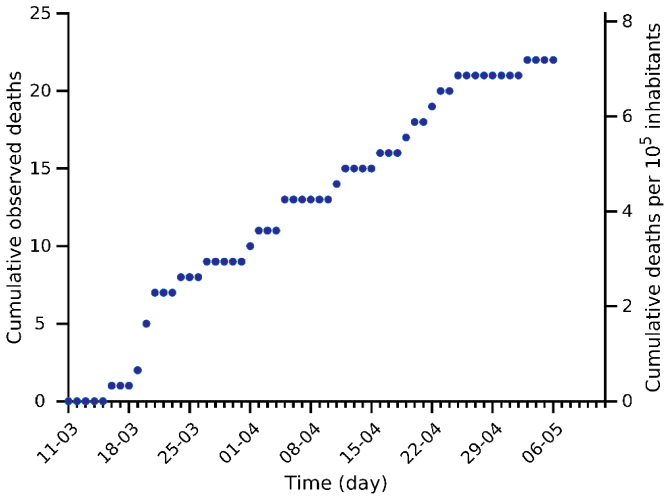


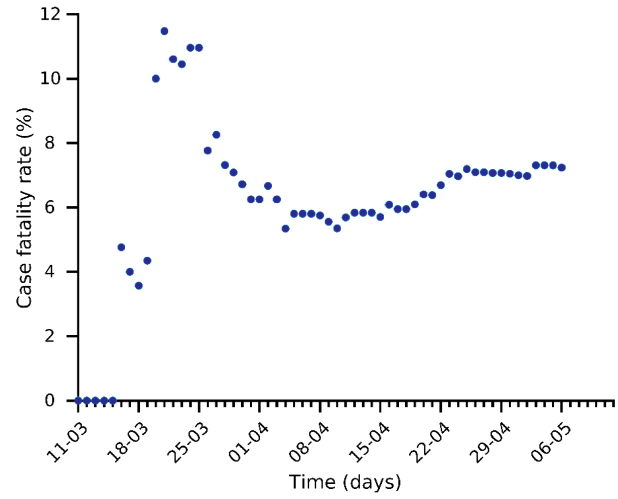












Methods

Methods

(1) Data source

Data are daily obtained from World Health Organization (WHO) surveillance reports[2], from European Centre for Disease Prevention and Control (ECDC)[3] and from Ministerio de Sanidad[4]. These reports are converted into text files that can be processed for subsequent analysis. Daily data comprise, among others: total confirmed cases, total confirmed new cases, total deaths, total new deaths. It must be considered that the report is always providing data from previous day. In the document we use the date at which the datapoint is assumed to belong, i.e., report from 15/03/2020 is giving data from 14/03/2020, the latter being used in the subsequent analysis.

(2) Data processing and plotting

Data are initially processed with Matlab in order to update timeseries, i.e., last datapoints are added to historical sequences. These timeseries are plotted for EU individual countries and for the UE as a whole:

- ✓ Number of cumulated confirmed cases, in blue dots
- ✓ Number of reported new cases
- ✓ Number of cumulated deaths

Then, two indicators are calculated and plotted, too:

- ✓ Number of cumulated deaths divided by the number of cumulated confirmed cases, and reported as a percentage; it is an indirect indicator of the diagnostic level.
- ✓ ρ: this variable is related with the reproduction number, i.e., with the number of new infections caused by a single case. It is evaluated as follows for the day before last report (*t-1*):

$$\rho(t-1) = \frac{N_{new}(t) + N_{new}(t-1) + N_{new}(t-2)}{N_{new}(t-5) + N_{new}(t-6) + N_{new}(t-7)}$$

where $N_{new}(t)$ is the number of new confirmed cases at day t.

(3) Classification of countries according to their status in the epidemic cycle

The evolution of confirmed cases shows a biphasic behaviour:

(I) an initial period where most of the cases are imported;
(II) a subsequent period where most of new cases occur because of local transmission.

Once in the stage II, mathematical models can be used to track evolutions and predict tendencies. Focusing on countries that are on stage II, we classify them in three groups:

- Group A: countries that have reported more than 100 cumulated cases for 10 consecutive days or more;
- Group B: countries that have reported more than 100 cumulated cases for 7 to 9 consecutive days;
- Group C: countries that have reported more than 100 cumulated cases for 4 to 6 days.

[2] https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports
[3] https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases
[4] https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov-China/situacionActual.htm
https://github.com/datadista/datasets/tree/master/COVID%2019 , https://covid19.isciii.es/

(4) Fitting a mathematical model to data

Previous studies have shown that Gompertz model[5] correctly describes the Covid-19 epidemic in all analysed countries. It is an empirical model that starts with an exponential growth but that gradually decreases its specific growth rate. Therefore, it is adequate for describing an epidemic that is characterized by an initial exponential growth but a progressive decrease in spreading velocity provided that appropriate control measures are applied.

Gompertz model is described by the equation:

$$N(t) = K\, e^{-ln\left(\frac{K}{N_0}\right)\cdot e^{-a\cdot(t-t_0)}}$$

where *N(t)* is the cumulated number of confirmed cases at *t* (in days), and N_0 is the number of cumulated cases the day at day t_0. The model has two parameters:

- ✓ *a* is the velocity at which specific spreading rate is slowing down;
- ✓ *K* is the expected final number of cumulated cases at the end of the epidemic.

This model is fitted to reported cumulated cases of the UE and of countries in stage II that accomplish two criteria: 4 or more consecutive days with more than 100 cumulated cases, and at least one datapoint over 200 cases. Day t_0 is chosen as that one at which *N(t)* overpasses 100 cases. If more than 15 datapoints that accomplish the stated criteria are available, only the last 15 points are used. The fitting is done using Matlab's Curve Fitting package with Nonlinear Least Squares method, which also provides confidence intervals of fitted parameters (*a* and *K*) and the R^2 of the fitting. At the initial stages the dynamics is exponential and *K* cannot be correctly evaluated. In fact, at this stage the most relevant parameter is *a*. Fitted curves are incorporated to plots of cumulative reported cases with a dashed line. Once a new fitting is done, two plots are added to the country report:

- ✓ Evolution of fitted *a* with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out;
- ✓ Evolution of fitted *K* with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out; if lower error bar indicates a value that is lower than current number of cases, the error bar is truncated.

These plots illustrate the increase in fittings' confidence, as fitted values progressively stabilize around a certain value and error bars get smaller when the number of datapoints increases. In fact, in the case of countries, they are discarded and set as "Not enough data" if $a>0.2\ day^{-1}$, if $K>10^6$ or if the error in K overpasses 10^6.

It is worth to mention that the simplicity of this model and the lack of previous assumptions about the Covid-19 behaviour make it appropriate for universal use, i.e., it can be fitted to any country independently of its socioeconomic context and control strategy. Then, the model is capable of quantifying the observed dynamics in an objective and standard manner and predicting short-term tendencies.

(5) Using the model for predicting short-term tendencies

The model is finally used for a short-term prediction of the evolution of the cumulated number of cases. The predictions increase their reliability with the number of datapoints used in the fitting. Therefore, we consider three levels of prediction, depending on the country:

[5] Madden LV. Quantification of disease progression. Protection Ecology 1980; **2**: 159-176.

- Group A: prediction of expected cumulated cases for the following 3-5 days[6];
- Group B: prediction of expected cumulated cases for the following 2 days;
- Group C: prediction of expected cumulated cases for the following day.

The confidence interval of predictions is assessed with the Matlab function `predint`, with a 99% confidence level. These predictions are shown in the plots as red dots with corresponding error bars, and also gathered in the attached table. For series longer than 9 timepoints, last 3 points are weighted in the fitting so that changes in tendencies are well captured by the model.

(6) Estimating non-diagnosed cases

Lethality of Covid-19 has been estimated at around 1 % for Republic of Korea and the Diamond Princess cruise. Besides, median duration of viral shedding after Covid-19 onset has been estimated at 18.5 days for non-survivors[7] in a retrospective study in Wuhan. These data allow for an estimation of total number of cases, considering that the number of deaths at certain moment should be about 1 % of total cases 18.5 days before. This is valid for estimating cases of countries at stage II, since in stage I the deaths would be mostly due to the incidence at the country from which they were imported. We establish a threshold of 50 reported cases before starting this estimation.

Reported deaths are passed through a moving average filter of 5 points in order to smooth tendencies. Then, the corresponding number of cases is found assuming the 1 % lethality. Finally, these cases are distributed between 18 and 19 days before each one.

[6] At this moment we are testing predictions at 4 days for countries with more than 100 cumulated cases for 13-15 consecutive days, and 5 days for 16 or more days.

[7] Zhou et al., 2020. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. The Lancet; March 9, doi: 10.1016/S0140-6736(20)30566-3